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AERIAL APPLICATIONS TECHNOLOGY PROGRAM PLANNING DOCUMENT

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AUGUST 1977

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C.

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1. INTRODUCTION

The Aerial Applications Technology Program Plan would promote national goals of increased agricultural productivity, energy conservation and improved environmental safeguards. The program plan would also respond to the needs of an important segment of the U.S. aviation community, specifically the agricultural aviation industry.

1.1 BACKGROUND

In November 1975, a special NASA working group undertook a study to assess the potential for improving agricultural productivity through advances in aeronautical technology. The study group collected agricultural aviation industry statistics; summarized the impacts of agricultural aircraft on U.S. and worldwide productivity; developed forecasts of future major roles for agricultural aircraft; listed major industry problems; recommended areas for aircraft and systems research efforts and potential payoffs for that research; and analyzed existing NASA research and technology (R&T) programs for applicability to agricultural aviation industry problems.

1.2 STUDY FINDINGS AND DISCUSSION[1]

The findings of this initial aerial application study are summarized as follows:

[1] "Agricultural Aviation Study and Program Plan," Volume I and II, National Aeronautics and Space Administration, June 1976.

- Agricultural aviation is important and its importance is expected to grow worldwide
- Substantial technical problems exist
- Solutions resulting in significant productivity increases, potential energy savings, and environmental improvements are possible
- Strong rationale exists for NASA involvement.

In 1976, about 7,300 agricultural aircraft (of a worldwide fleet numbering about 25,000) were in service in the U.S. They flew approximately 2 million flight hours and treated an estimated 245 million acres (multiple applications included). The industry is currently growing at approximately 10 percent per year due in part to the superiority of aerial application to ground application in several areas. Some examples of these areas are as follows:

- Crop management

  Aerial application enables farmers to meet optimum planting dates; to apply chemicals at agrinomically optimum periods; and to ready crops for harvest at opportune times.

- Soil compaction avoidance

  Aerial application eliminates soil compaction caused by the weight of ground application equipment. Crop production is increased and noncompacted soil provides greater resistance to drought through improved moisture retention.

- Inaccessible ground conditions

  Aerial application affords the opportunity to apply chemicals to land, especially range land, that is otherwise inaccessible to ground application equipment.

- Rapid response to ground infestation

  Aerial application enables farmers to combat infestations over large areas in short periods of time. In addition, aerial application is not hindered by wet ground, a condition which can preclude the use of ground equipment.

Agricultural aviation impacts on a number of areas including seeding, fertilizing and pesticiding, harvesting, range and forest management, and wide area pest control. Projected increases in minimum-till farming, in pesticide use, and in the use of liquid spray methods for application, all point to increased demand for aerial application services.

Interavia estimates that the worldwide agricultural aviation fleet numbers approximately 25,000 aircraft, an increase of 7 percent since December 1975.[2]

The most widely used agricultural aircraft in the world today are the Polish-built AN-2 aircraft. Over 11,000 AN-2 aircraft have been produced with the vast majority being used for aerial application. While the USSR has been the major recipient, units have also been exported to Bulgaria, Czechoslovakia, France, the German Democratic Republic, Hungary, North Korea, Mongolia, The Netherlands, Romania, and Yugoslavia. In addition, Polish-operated teams of AN-2s have carried out extensive agricultural operations in Algeria, Egypt, Ethiopia, Hungary, the Sudan and Tunisia. Production of the AN-2 will soon be phased out in favor of the M-15, a joint Russo-Polish aircraft displayed in Figure 1.1. The USSR has already announced plans to purchase 3,000 M-15 aircraft which will carry a 75-percent greater payload than the AN-2 and have a doubled swath width. The significant features of these aircraft are their payload and coverage capabilities. Some comparisons with U.S. aircraft are shown below:

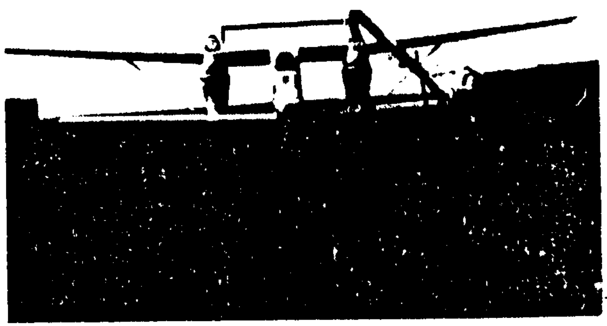
Aircraft	Payload	Swath Width
Piper Pawnee Brave	1,900 lbs	70 ft
Grumman Ag Cat	2,000 lbs	54 ft
AN-2	2,650 lbs	102 ft
M-15	4,850 lbs	225 ft

Factors pointing toward increased use of agricultural aviation in developing nations are presented in Figure 1.2.

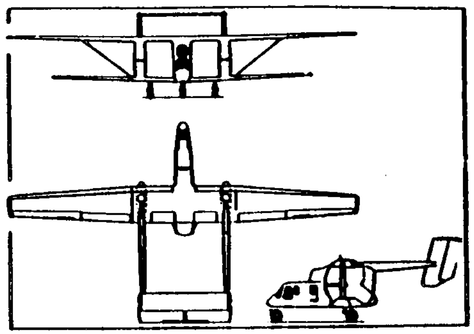
The needs of emerging nations may be served best by larger aircraft than the U.S. currently manufactures. Some operations taking place such as the World Health Organization Volta River Basin project, require aircraft of a larger size than U.S. production models. The workhorse aircraft for Ciba-Geigy, Limited, a company that has conducted extensive aerial application operations in developing nations, is the Pilatus Turbo-Porter which is again larger than U.S. models. To remain competitive in the international market and to realize desired growth in annual exports, U.S. manufacturers may have to develop new, perhaps larger, more productive agricultural aircraft.

[2] "Agricultural Aviation - Feeding the World," Interavia, December 1975

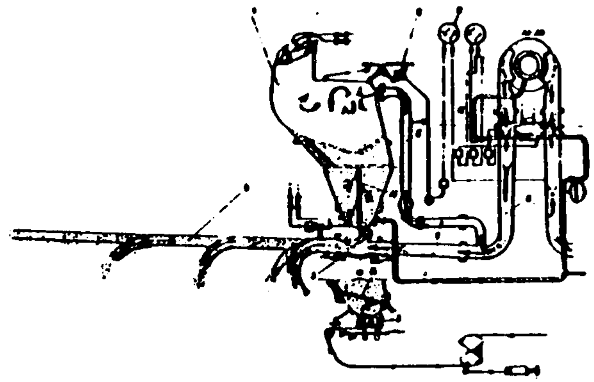
SOVIET/POLISH M-15 AIRPLANE



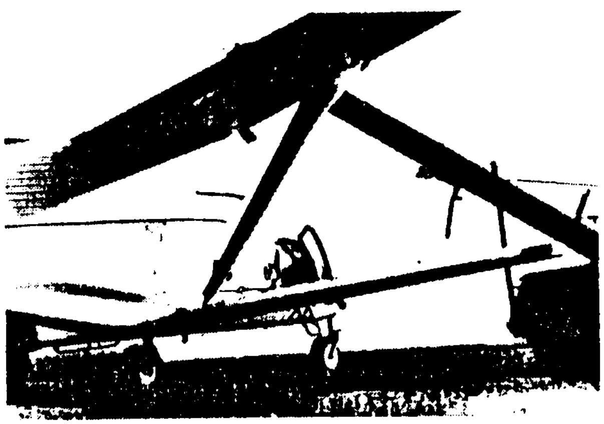
CLOSED LOADING
OPERATIONS



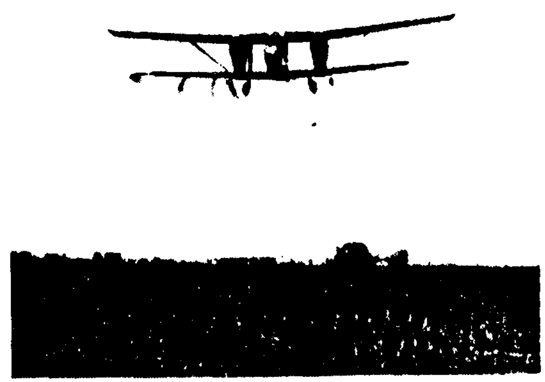
AIRPLANE
THREE VIEW SKETCH



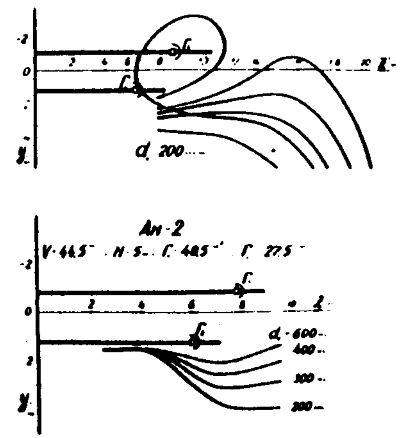
BLEED AIR DRIVEN
DISPERSAL SYSTEM



INTERNAL, LOWER WING
DISPERSAL SYSTEM



DRY MATERIALS DISPERSAL
DEMONSTRATION



THEORETICAL ANALYSIS
OF PARTICAL TRAJECTORIES

FIGURE 1.1

FACTORS POINTING TOWARD INCREASED USE OF AERIAL APPLICATIONS IN DEVELOPING NATIONS

- ONGOING PROGRAMS
  - WORLD HEALTH ORGANIZATION – 20 YEAR, $120 MILLION PROGRAM IN VOLTA RIVER BASIN TO COMBAT PARASITIC INFECTION
  - CIBA-GEIGY AERIAL APPLICATIONS IN JAVA TO COMBAT STEMBORERS (1 MILLION HECTARES TREATED 4 TIMES PER YEAR DURING PERIOD 1968-1970)
  - SIMILAR CIBA-GEIGY OPERATIONS IN BANGLADESH, IRAN, PAKISTAN, SUDAN, EGYPT, SAUDI ARABIA, INDONESIA, MOROCCO, GHANA, NIGERIA, ZAIRE AND THE CENTRAL AFRICAN REPUBLIC
- INCREASING FOOD SHORTAGES
- CONCERN FOR INCREASED AGRICULTURAL PRODUCTIVITY

FIGURE 1.2

A number of problems associated with agricultural aviation are depicted in Figure 1.3. Many of the problems are interrelated and all appear to fall within areas where NASA can bring considerable expertise to bear.

1.3 NASA FOLLOW-ON ACTIVITIES

The results of the technology assessment study prompted continued NASA efforts in the agricultural aviation field including such activities as economic analyses and user requirements studies, results of which are included in appendices A and B respectively. Emphasis is being placed on relating each of the problem areas to unique NASA capabilities in terms of relevant past experience and facilities. Figure 1.4 illustrates one such example of exploratory tests of the effect of the aircraft wake on the eveness of the material deposited on the ground.

1.4 TIMELINESS

Since November, 1975, NASA's activities in agricultural aviation have included participation in national and state agricultural association meetings and workshops. This continuous interface has resulted in a program that is responsive to pressing industry needs, and which is supported by the diverse segments of the agricultural industry including aerial operators, airframe and equipment manufactures, chemical manufactuers, and the research community.

Support for the aerial applications technology program is also evident among state and federal levels of government. In response to queries to the governors of the fifty states by Senator Moss, thirty-seven replies highly endorsed early initiation of a NASA-sponsored research and technology program.

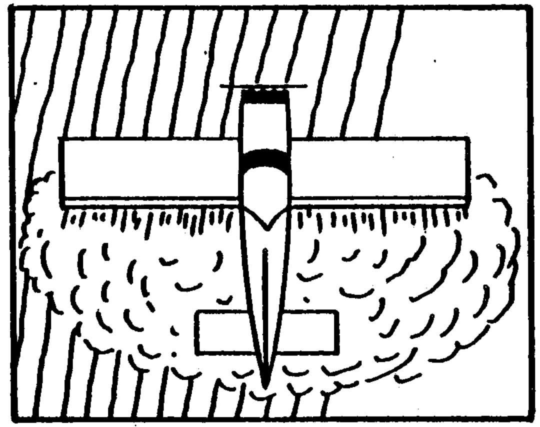
Support from the USDA, the EPA, and the FAA is manifested by their planned participation in the program through interagency agreements (Appendix C).

Continuing developments in agricultural chemicals and materials underscore the need for concurrent research efforts in application technology.

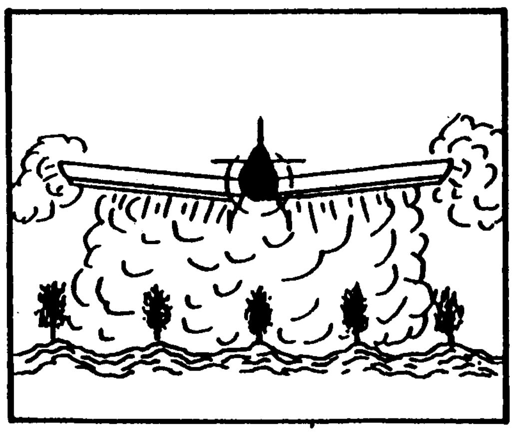
This inclusive support, coupled with the Administration's call for energy conservation and preservation of the environment, underlines the need for initiating the Aerial Applications Program at this time.

PROBLEMS IN AGRICULTURAL AVIATION

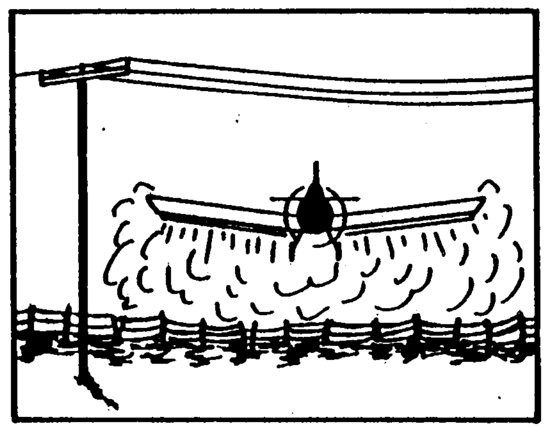
- DRIFT (CHEMICAL LOSSES)
- DISPERSAL SYSTEM CALIBRATION
- ENGINE RELIABILITY
- CRASHWORTHINESS
- COCKPIT ENVIRONMENT
- CORROSION CONTROL
- SHORTFIELD PERFORMANCE
- FERRY SPEED



DISTRIBUTION SYSTEM ACCURACY



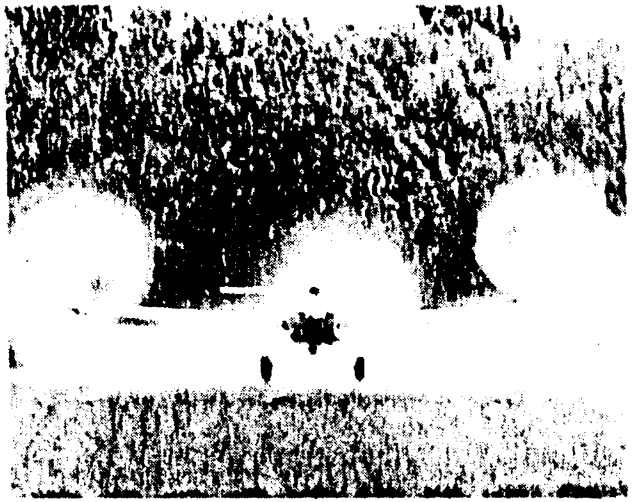
AERODYNAMIC INTERACTION WITH DISTRIBUTION SYSTEM



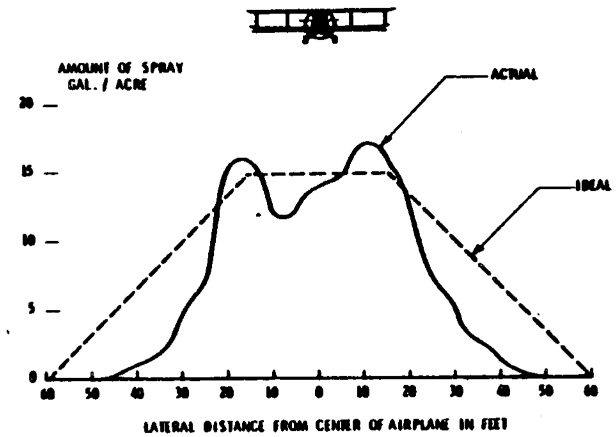
HANDLING QUALITIES
MANEUVERABILITY
PERFORMANCE

FIGURE 1.3

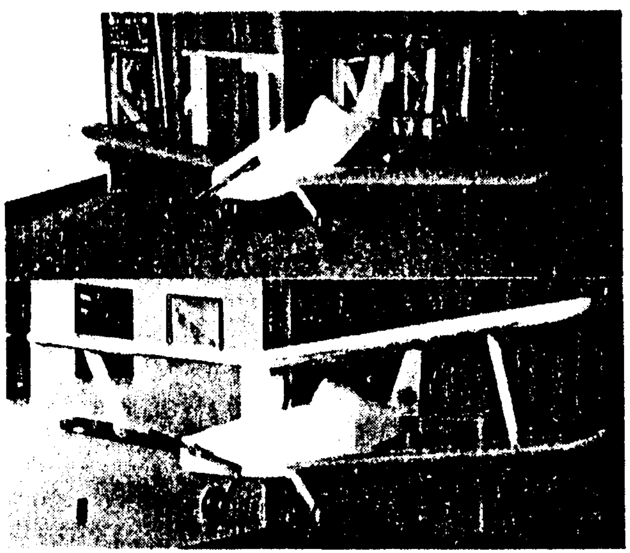
RESEARCH ON WAKE INTERACTIONS FOR AGRICULTURAL AIRCRAFT



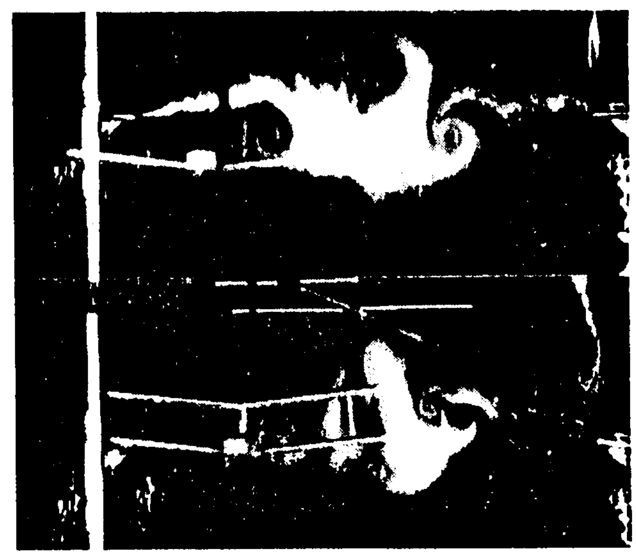
EXAMPLE OF
SPRAY-WAKE INTERACTION



EFFECT OF INTERACTION
ON DISTRIBUTION



RESEARCH MODELS



FLOW VISUALIZATION IN
LANGLEY VORTEX FACILITY

FIGURE 1.4

2. PROGRAM OBJECTIVES

2.1 BROAD OBJECTIVES

The broad objectives of the Aerial Applications Technology Program are to develop new technologies that will result in short-, mid-, and long-term improvements in agricultural aircraft performance and dispersal system efficiency. Such improvements could:

- Increase the productivity and safety of agricultural aircraft
- Promote more productive use of scarce energy resources
- Enhance the development of improved environmental safeguards through more efficient use of agricultural chemicals.

To achieve these broad objectives, NASA would apply expertise in diverse disciplines to improve the effective utilization of agricultural aircraft.

2.2 SPECIFIC OBJECTIVES

The Aerial Applications Technology Program would be directed toward the attainment of the following specific objectives:

- Standardization of dispersal system calibration equipment and methods
- Understanding the effects of aircraft wake, atmospheric conditions, and dispersal system characteristics on distribution patterns
- Development of advanced dispersal system concepts which account for such variables as chemical formulations, wake

interaction, target characteristics, atmospheric conditions, and mission requirements

- Development of improved swath guidance system concepts
- Development of aircraft handling qualities criteria for improved aerial applications mission performance, and flight path control concepts
- Development of improved materials technology for airframe and dispersal systems
- Development of technologies for improving overall propulsion system efficiency including the generation and use of auxiliary power
- Development of concepts for improved safety and human factors design of aircraft systems
- Evaluation of aerodynamic concepts for improved take-off and landing, turning, and stall characteristics.

2.3 RELATIONSHIP TO NASA GOALS

NASA's goals are delineated in its charter, the National Aeronautics and Space Act of 1958. The research activities defined for the Aerial Applications Technology Program would contribute to the objectives of this Act.

2.4 RELATED ACTIVITIES

The Aerial Applications Technology Program is related to and would draw upon expertise from ongoing R&T activities in:

- Trailing vortex phenomena
- Stall/spin
- Drag reduction
- Propulsion efficiency
- Flight simulation
- Crashworthiness
- Aero-acoustics
- Stability and control
- Materials
- Airfoil/high-lift concepts
- Navigation guidance

- Nozzle performance
- Laser sensing and tracking
- Human factors.

None of the suggested activities in the Aerial Applications Technology program would preclude the continuation of ongoing general aviation research efforts.

3. TECHNICAL PLAN

This section describes the program definition activities and the technical content of the Aerial Applications Technology Program. An overview of the technical plan (Figure 3.1) indicates the program would consist of four parts that would run concurrently from YR 1 through YR 7 of the program. The figure also lists the major task areas that would be considered under each program part.

3.1 PROGRAM DEFINITION PHASE

Although the program definition activities are not part of the proposed program, they are significant prerequisite activities. Consequently, they will be described here. The program definition activities consist of the following tasks:

- Task 1 - Program development activities
- Task 2 - Application, refinement, and development of NASA capabilities
- Task 3 - Calibration system development

Task 1 - Program Development Activities

The overall objectives of this task are to thoroughly define the needs of the agricultural aviation industry and to assess the role of research and technology in improving aerial application aircraft and systems. The following activities have been or will be performed in support of this task:

AERIAL APPLICATIONS TECHNOLOGY

OVERVIEW OF TECHNICAL PLAN

FY 77	FY 78	NEW START YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7

PROGRAM DEFINITION PHASE

- Program Development Activities
- Application Refinement and Development of NASA Capabilities
- Calibration System Development

PART 1.0.0.0 SYSTEMS ANALYSIS

- Innovative Systems Analysis
- Technical Integration & Application Analysis
- Environmental Analyses
- Economic Analyses

PART 2.0.0.0 FIELD CALIBRATION SYSTEM TECHNOLOGY

- Standardized Calibration Equipment & Methods
- Flight Research Support
- Atmospheric Modeling

PART 3.0.0.0 AIRCRAFT SYSTEM

- Wake Interactions
- Dispersal Systems
- Swath Guidance Systems
- Handling Qualities Criteria
- Airframe & Dispersal System Materials
- Propulsion Systems
- Cockpit/Systems Design
- Aircraft Aerodynamics

PART 4.0.0.0 SYSTEMS DEMONSTRATION

- System Integration & Design
- System Construction
- Aircraft Modification
- System Evaluation

Problem Definition	Existing Equipment Documentation Operational Data	Subsystem Design Alternatives Short Term Improvements	Long Term Improvements New Aircraft Concepts

FIGURE 3.1

- Agricultural Aviation Research Workshop

  A workshop was conducted at Texas A&M University in October 1976. Scientists, engineers, operators and manufacturers from the aerial applications community joined NASA representatives in reviewing and evaluating industry state-of-the-art, in identifying and prioritizing research requirements, and in determining a match between industry research needs and NASA capabilities.

- Benefit/Cost Analysis

  Under NASA contract, ECON Incorporated has completed a benefit/cost analysis which indicates that significant benefits can be realized through improvements in aerial applications technology. Study results form the basis for the economic benefits presented in Appendix A.

- User Requirements Study

  Under NASA contract, Actuarial Research Corporation conducted a survey of agricultural aviation operators to collect further data in regard to problems impacting on aerial application operations. Study results (summarized in Appendix B) include a statistical weighting of problems and indicate that major problems, such as drift control, exist in areas where NASA expertise can be applied.

- Contractor/Consultant Program Analyses

  Under NASA contract, contractors and consultants are currently supporting Langley Research Center, Wallops Flight Center, and Lewis Research Center in the development of specific research goals and tasks which will bring NASA expertise to bear in potentially high pay-off areas.

- American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program

  The Langley Research Center is currently sponsoring a systems study by a group of twenty college and university faculty members relevant to the role of aeronautics and space in agriculture. The group is concentrating its efforts on the pontential of aeronautics (aerial application) and space (remote sensing) for improving agricultural productivity.

- System Design Studies

  The Langley Research Center is initiating conceptual design studies for large and small fixed-wing and for rotary wing aircraft. The objective of these studies is to generate innovative concepts for aerial application systems.

- Foreign Market Study

  The Langley Research Center will sponsor a study to define the potential roles and impacts of agricultural aircraft in developing nations.

Task 2 - Application, Refinement, and Development of NASA Capabilities

The objective of this task is to establish the capability for conducting an effective research program in aerial applications. Existing techniques are being refined and new ones developed as described in the following paragraphs:

- Wake Vortex Computer Code Refinement

  Under Langley Research Center contracts and grants, computer programs have been and are being developed along with particle trajectory scaling laws to predict trajectories and distribution patterns of agricultural materials in an aircraft wake. A number of dispersal systems and concepts for wake modification will be modeled to guide vortex facility, wind-tunnel, and flight research.

- Vortex Facility Testing

  Tests in the Langley Vortex Research Facility will utilize flow visualization and rapid scan laser velocimetry to monitor near- and far-field wake transport in ground effect. Tests with the following scale models are planned:

  - Thrush Commander 800
  - Turbo-Thrush
  - Ag-Cat
  - Turbo-Cat
  - Russian/Polish M-15

  These models will be equipped with dispersal systems for both liquid and solid materials to examine the interactions of the basic wake vortex system with both liquid and dry materials.

- Full-Scale Tunnel Testing

  The application of the Langley full-scale tunnel for study of agricultural aircraft will yield important research information to serve as a data base for further work. Tests with the following full-scale aircraft are planned:

  - Thrush
  - Ag-Cat

- Preliminary Flight Demonstrations

  Preliminary flight experiments will be designed to evaluate current field monitoring techniques, new concepts in laser and radar measurement instrumentation, and to provide correlation with model tests.

- Swath Guidance Signal/Display Evaluations

  Both off-the-shelf and breadboard avionics and display equipment will be tested to establish criteria for the technology development phase of swath guidance systems research.

- Handling Qualities Criteria Development

  Under NASA contract, a variable stability airplane will be employed to study optimal longitudinal and lateral-directional handling qualities for fixed-wing aerial application aircraft.

- Augmented VGH Recorder Program

  Flight recorders giving a time history of indicated airspeed (V), normal acceleration (G), and pressure altitude (H) are installed in 21 aerial application aircraft. Data from these recorders will be used to define operating practices, describe flight load experience, and compare the operations of the reciprocating- and turbine-engine aircraft.

Task 3 - Calibration System Development

The objective of this task is to develop techniques for evaluating the performance of aircraft dispersal systems. This task will be performed at the Wallops Flight Center. The following efforts will take place in support of this task:

- Development of Liquid/Dry Collection Rig

  For dispersal system testing, two-dimensional arrays of Kromecote cards, mylar sheets, and collection hoppers will be used. Methods will be investigated for determining deposition of materials in wakes.

- Laser-Doppler Velocity Profiles

  A laser-doppler velocimeter will be tested to determine its capabilities for measuring cloud drift and spray concentration with time. Various optical techniques will be examined, including laser shadowgraphs (to measure particle-size distribution) and photography.

- Laser-Fluorosensor Evaluation

  The capabilities of a laser-fluorosensor will be investigated. This unit measures the fluorescence generated when a laser beam irradiates a treated object on the ground. The amount of return gives an indication of the coverage and the amount of deposit on any given field.

- Meteorological Modeling and Analysis

  Contract studies of microatmospheric modeling techniques will be initiated to provide a better understanding of the behavior of particles in the flow field.

3.2 AERIAL APPLICATIONS TECHNOLOGY PROGRAM

The Aerial Applications Technology Program would contain the elements which appear in the work breakdown structure diagram (Figure 3.2). The major parts of the program would be as follows:

- Part 1.0.0.0 - Systems Analysis
- Part 2.0.0.0 - Field Calibration System Technology
- Part 3.0.0.0 - Aircraft Systems
- Part 4.0.0.0 - Systems Demonstration

Major tasks and subtasks are listed in a detailed work breakdown structure (Figure 3.3) and are described in further detail below.

3.2.1 Part 1.0.0.0 - Systems Analysis

This part consists of the following four tasks as indicated in Figure 3.3 Langley Research Center would have responsibility for these tasks.

- Task 1.1.0.0 - Innovative System Analyses

  On a continuing basis, work would be undertaken to identify alternative, innovative systems and technology concepts to meet existing and anticipated aerial applications mission requirements.

- Task 1.2.0.0 - Technical Integration and Application Analyses

  Concepts developed as a result of both the innovative system studies and in-house research would undergo technical analysis in mission applications studies. Such studies would identify technical obstacles involved in integrating system technologies and would evaluate the operational capabilities of these concepts applied in any specific aerial applications mission.

- Task 1.3.0.0 - Environmental Analyses

  Evaluation of system or technology concepts would include an analysis of operational environmental impact.

- Task 1.4.0.0 - Economic Analyses

  Research program planning would continually utilize macro- and microeconomic models synthesizing the agricultural industry and aerial applications mission operations to further evaluate the economic feasibility of proposed system concepts.

WORK BREAKDOWN STRUCTURE DIAGRAM

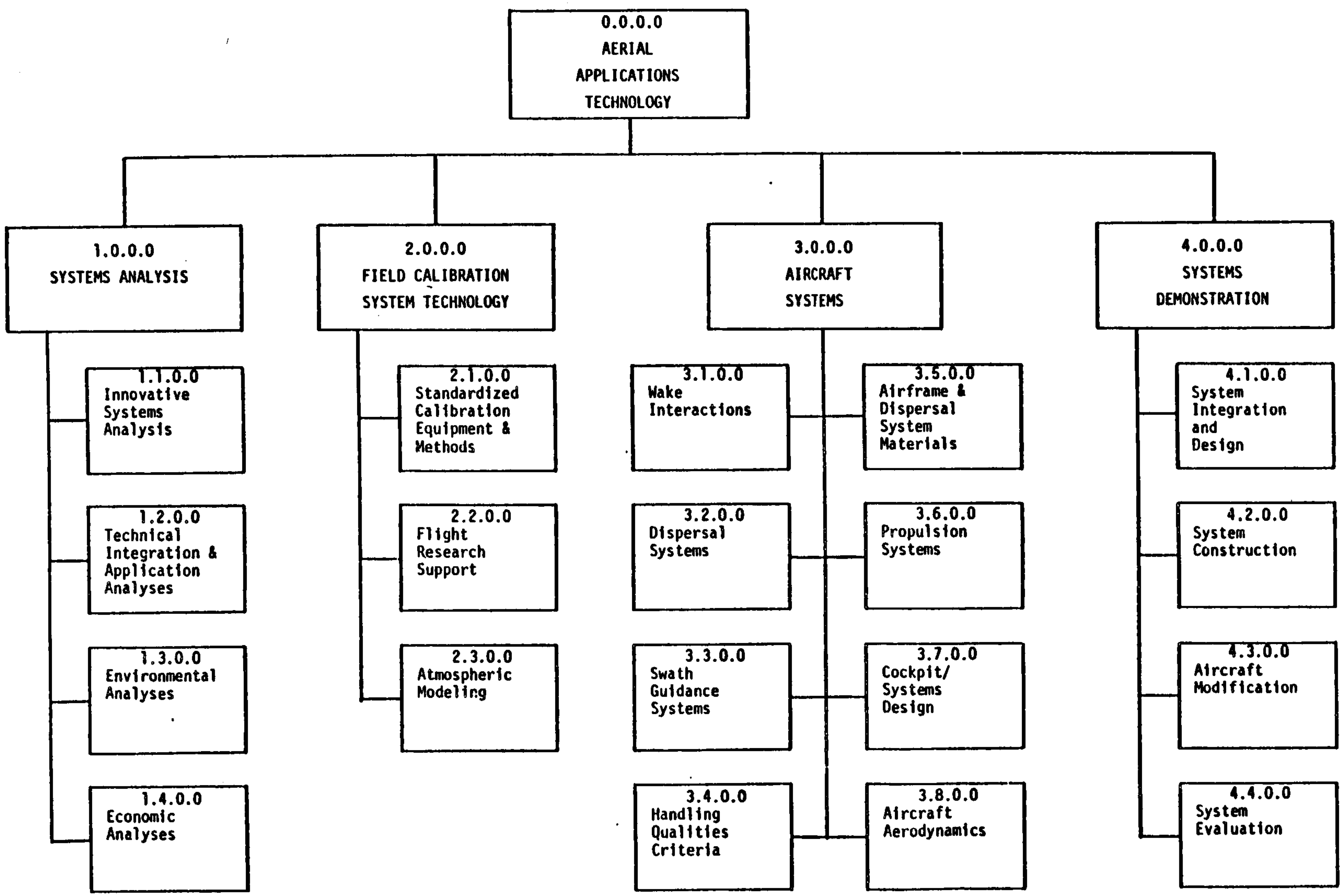


FIGURE 3.2

Level 1 Program Code	Level 2 Part Code	Level 3 Task Code	Level 4 Subtask Code	Description
0.0.0.0				AERIAL APPLICATIONS TECHNOLOGY
	1.0.0.0			SYSTEMS ANALYSIS
		1.1.0.0		INNOVATIVE SYSTEM ANALYSES
		1.2.0.0		TECHNICAL INTEGRATION AND APPLICATION ANALYSES
		1.3.0.0		SYSTEM SAFETY AND ENVIRONMENTAL ANALYSES
		1.4.0.0		ECONOMIC ANALYSES
	2.0.0.0			FIELD CALIBRATION SYSTEM TECHNOLOGY
		2.1.0.0		STNADARDIZED CALIBRATION EQUIPMENT AND METHODS
		2.2.0.0		FLIGHT RESEARCH SUPPORT
		2.3.0.0		ATMOSPHERIC MODELING
	3.0.0.0			AIRCRAFT SYSTEMS
		3.1.0.0		WAKE INTERACTIONS
			3.1.1.0	DEVELOPMENT OF WAKE MODIFICATION CONCEPTS
			3.1.2.0	INTEGRATION OF DISPERSAL SYSTEM DESIGN WITH WAKE CHARACTERISTICS
		3.2.0.0		DISPERSAL SYSTEMS
			3.2.1.0	DEVELOPMENT OF ADVANCED LIQUID DISPERSAL SYSTEM CONCEPTS
			3.2.2.0	DEVELOPMENT OF ADVANCED DRY SPREADER SYSTEM CONCEPTS
			3.2.3.0	OPERATOR DATA BOOK FOR OPTIMAL APPLICATION PRACITCES
			3.2.4.0	D.SPERSAL SYSTEM CONTROL TECHNOLOGY
		3.3.0.0		SWATH GUIDANCE SYSTEMS
		3.4.0.0		HANDLING QUALITIES CRITERIA
			3.4.1.0	DEVELOPMENT OF STABILITY AND CONTROL REQUIREMENTS FOR FIXED AND ROTARY WING AIRCRAFT
			3.4.2.0	DIRECT FORCE CONTROL CONCEPTS
			3.4.3.0	FLIGHT PATH CONTROL AUGMENTATION CONCEPTS
		3.5.0.0		AIRFRAME AND DISPERSAL SYSTEMS MATERIALS
			3.5.1.0	EVALUATION OF CORROSION, EROSION RESTRAINT MATERIALS FOR BASIC AIRFRAME AND DISPERSAL SYSTEMS
			3.5.2.0	VGH DATA ANALYSIS
			3.5.3.0	APPLICATION OF COMPOSITE TECHNOLOGY
		3.6.0.0		PROPULSION SYSTEMS
			3.6.1.0	ANALYSIS OF DISPERSAL AND AUXILIARY SYSTEM POWER REQUIREMENTS
			3.6.2.0	COMPARATIVE ANALYSIS OF ALTERNATIVE PROPULSION SYSTEMS
		3.7.0.0		COCKPIT/SYSTEMS DESIGN
			3.7.1.0	EVALUATION OF CRASHWORTHINESS DESIGN CONCEPTS
			3.7.2.0	EVALUATION OF IMPROVED FIREPROOFING MATERIALS
			3.7.3.0	DEVELOPMENT OF COCKPIT ENVIRONMENTL CONTROL SYSTEMS
			3.7.4.0	COCKPIT HUMAN FACTORS DESIGN CONCEPTS
		3.8.0.0		AIRCRAFT AERODYNAMICS
			3.8.1.0	EVLAUATION OF THICK LOW-SPEED AIRFOILS
			3.8.2.0	EVALUATION OF HIGH LIFT SYSTEM CONCEPTS
			3.8.3.0	TURNING PERFORMANCE
			3.8.4.0	EVLAUATION OF STALL CHARACTERISTICS
	4.0.0.0			SYSTEMS DEMONSTRATION
		4.1.0.0		SYSTEMS INTEGRATION AND DESIGN
		4.2.0.0		SYSTEMS CONSTRUCTION
		4.3.0.0		AIRCRAFT MODIFICATION
		4.4.0.0		SYSTEM EVALUATION

FIGURE 3.3 DETAILED WORK BREAKDOWN STRUCTURE

3.2.2 Part 2.0.0.0 - Field Calibration System Technology

Wallops Flight Center would have primary responsibility for the efforts under this part, which would consist of the following three tasks:

- Task 2.1.0.0 - Standardized Calibration Equipment and Methods

  Practical calibration systems and techniques would be developed which could be used by operators to field-check and validate the performance of their equipment.

- Task 2.2.0.0 - Flight Research Support

  Support would be provided for flight experiments on a continuous basis to provide documentation of aircraft dispersal system performance.

- Task 2.3.0.0 - Atmospheric Modeling

  Microatmospheric models would be integrated with wake vortex models to provide a better understanding of the vehavior of particles in the flow field.

3.2.3 Part 3.0.0.0 - Aircraft Systems

Both Langley Research Center and Lewis Research Center would be responsible for the efforts under this part, which would consist of the following tasks and subtasks:

- Task 3.1.0.0 - Wake Interactions

  Langley Research Center would be responsible for this task and would utilize the vortex flow facility, the full-scale wind tunnel, flight research, and computational techniques. Conventional and advanced dispersal system concepts would be integrated with wake modification methods to enhance transport and reduce drift of liquid and dry materials.

  - Subtask 3.1.1.0

    An important program element would be studies related to the interaction between the aircraft wake and the dispersed chemicals. Numerical analyses and scale model tests in the Vortex Research Facility would be expected to provide understanding of the dynamics of wake-particle interactions. Candidate methods for obtaining interactions more favorable to wide, uniform chemical distribution patterns would be identified and developed, and more promising concepts would be evaluated in full-scale tunnel and flight tests.

Judicious aerodynamic modification of wake characteristics is believed to be one means by which more favorable flow interactions may be obtained. The lift-induced vortex, particularly when in ground effect, provides an important mechanism for lateral transport of particles dispersed from the aircraft. Lighter particles, however, can become entrained in the vortex and are then subject to drift. Proper management of shed lift-induced vorticity may be necessary for control of particle transport. Some candidate wake modification concepts to be investigated would include nonplanar lifting surfaces (winglets), segmented flaps, wing upper-surface fins (side-force vortex generators), and blowing, on both monoplane and biplane configurations.

- Subtask 3.1.2.0

Conventional and advanced dispersal system concepts would be integrated with wake modification methods to enhance transport and reduce drift potential. Initial investigations would establish effects of boom location, nozzle spanwise location, spanwise variation of droplet size, nozzle orientation with respect to local flow, and deposit ejection rate. Subsequent investigations would evaluate novel concepts such as powered, internally ducted, dispersal systems.

- Task 3.2.0.0 - Dispersal Systems

Langley Research Center would be responsible for dry dispersal systems and Lewis Research Center would be responsible for liquid dispersal systems under this task. These efforts would be directed toward the development of advanced dispersal system technology demonstrating improved confinement and uniformity of dispersion within the target area.

- Subtasks 3.2.1.0

Nearly all of the currently operational spray systems emit a broad spectrum of droplet sizes which increase potential for drift and evaporation of the smaller particles. Controlling spay drop size appears to be the most logical approach to reducing the aerial transport or drfit of these small spray droplets. A variety of nozzle designs and spray concepts for controlling droplet size would be generated. The most promising designs and concepts would then be selected and used to fabricate working models for testing the isolated nozzles in high velocity airstreams. The performance of each model would be evaluated on the basis of the drop-size distribution and persistence, drop velocity, drop trajectory, and other performance criteria. High performance spray nozzles would then be incorporated into spray systems for screening studies, and finally, flight test verification of systems performance. Inefficiency in fluid pumps contributes to fuel waste and higher costs per treated acre. Valves too often fail to effect a complete shut-off, permitting chemicals to be dribbled away into the local environment. The application of modern technology could alleviate these difficulties through the development of advanced liquid dispersal systems technology.

- Subtask 3.2.2.0

The objective of the dry spreader system concepts subtask would be to provide data for the design of advanced dry materials spreader systems. Current venture type spreaders fail to distribute dry materials evenly over a given swath especially for large swath widths. This non-uniformity of coverage results in too much treatment in some areas, too little in others, and thus a net loss in application efficiency. Furthermore, the limitation on swath width acts as a fundamental barrier to lowering distribution costs. New spreader concepts or designs are needed to overcome these limitations.

Through analytical and experimental investigations, existing dispersal system limitations would be identified in detail, and a data base would be developed which would serve as a starting point for advanced research. Near term efforts would provide technology for reduced drift and improved dispersal patterns through optimized wake interactions, and for improved aircraft performance through reduced dispersal system power requirements.

Long term research efforts, guided by near term results and market and mission system study predictions would be pointed towards advanced, powered, internal dispersal systems which would be aerodynamically and economically efficient in providing increased productivity in high volume mission operations.

- Subtask 3.2.3.0

The purpose of the operators' data book would be to widely disseminate data, based on best available research results, about practical application practices which produce known good results. This work would require systematic verification of dispersal system performance throughout various regimes of droplet size, chemical characteristics, aircraft operating speed, altitude, and atmospheric conditions. With such a guide, variations in air temperature, humidity, and crosswinds, for example, could be accounted for in a more precise, consistent, and scientifically-based manner.

- Subtask 3.2.4.0

  The dispersal system controls effort would involve controlling dispersal system parameters such as spray-rate with aircraft ground speed and other variables to obtain a more uniform dispersion and reduced pilot workload.

  In an ideal situation, the chemicals will flow out of the dispersal system at a constant rate. In practice, however, variations in air speed, wind, and altitude require continuous flow rate adjustments to avoid pattern dispersions in the target area. The component technologies required to develop an automated spray control are well matured (microprocessors for example) and need only be merged with attention to cost savings and reliability.

- Task 3.3.0.0 - Swath Guidance Systems

Langley Research Center would be responsible for this task and would utilize simulation facilities and flight research for concept evaluation and development. Tests and studies would be made to define the accuracy, reliability, and signal strength requirements for various guidance system concepts. The requirements for and ability of pilots to utilize the information would be determined.

- Task 3.4.0.0 - Handling Qualities Criteria

Langley Research Center would have primary responsibility for this task. Fixed-base and in-flight simulation would provide information for determining agricultural aircraft stability and control requirements suited to aerial applications missions. Based on these requirements, alternative control concepts could be evaluated.

- Subtasks 3.4.1.0

  In flight simulation with variable stability aircraft could be an important tool in determining stability and control requirements. Other important tools could be the current aerial applications aircraft, which would provide baseline data and fixed base simulation. Research in the area of stalls and spins would be handled by Langley wind tunnel, free flight and drop model facilities.

- Subtask 3.4.2.0

  Direct lift, drag, and side force control concepts would be examined to permit more precise flightpath and aircraft attitude control. More precise tracking of good guidance signals revolves about the ability to apply forces to the aircraft in a timely and accurate manner, often with certain constraints peculiar to the aerial applications mission. It would be necessary to thoroughly investigate the following as a result of direct force implementation: undesirable force and moment couplings, changes in basic aircraft longitudinal and lateral-directional characteristics, changes in drag, stall behavior changes, effects on propulsive efficiency, effects on aircraft wake and particle trajectories and cockpit control arrangements for commanding direct forces.

- Subtask 3.4.3.0

  Based on the availability of sufficiently accurate swath guidance signals, concepts would be evaluated for providing flight path control augmentation for aircraft positioning in the swath run for very large area missions. Concepts such as separate surface systems, which provide flight path control while giving the pilot full authority, would be evaluated. Such systems could provide increased application accuracy and reduced pilot workload.

● Task 3.5.0.0 - Airframe and Dispersal Systems Materials

Both Langley and Lewis Research Centers would pursue efforts under this task. Materials technology would be sought for resistance to agricultural chemical-induced corrosion and erosion, and for lighter, stronger, low-cost airframe and propeller structures.

- Subtask 3.5.1.0

  Materials technology would be sought for resistance to agri-chemical induced corrosion and erosion, and for lighter, stronger low cost airframe and propeller structures.

- Subtask 3.5.2.0

  NASA's ongoing VGH program (VGH = velocity, load factor and altitude recorders for gathering field data on aircraft load experience) would provide information to evaluate mission profiles and aircraft fatigue.

- Subtask 3.5.3.0

  An investigation would be conducted to determine the suitability of implementing composite materials into the design of agricultural aircraft and dispersal systems.

- Task 3.6.0.0 - Propulsion Systems

  Lewis Research Center would have primary responsibility for this task. This effort would be planned to identify and demonstrate technology capable of improving the auxiliary and flight power system efficiency of aerial applications aircraft.

  - Subtasks 3.6.1.0

    An analysis of dispersal and auxiliary system power requirements for future wet and dry dispersal systems would be conducted. This would include the identification of desirable power characteristics such as: amount, type, rotational speed range, load modulation, and duty cycle. It would also include an assessment of technology deficiencies in the auxiliary power components. One or two study efforts would be carried out by teams of dispersal and power system analysts.

  - Subtasks 3.6.2.0

    A comparative analysis of alternative propulsion systems including reciprocating, Wankel, and turbine engines for both airplane and helicopter applications would be conducted. Further study of the entire power system, including the auxiliary power devices on an integrated system combination, would be required. An assessment would be made of technology deficiencies associated with propulsion and auxiliary power systems. Two parallel studies would be carried out by teams of engine manufactureres and auxiliary power system analysts.

- Task 3.7.0.0 - Cockpit/Systems Design

  Langley Research Center would have primary responsibility for this task. Studies would be conducted to evaluate crashworthiness design concepts, improved fire protection concepts, cockpit environmental control system requirements, and cockpit human factors design concepts.

  - Subtask 3.7.1.0

    As part of the evaluation of crashworthiness design concepts, the following areas would be investigated:

    - failure modes of cockpit peripheral structure
    - pilot seat design
    - pilot restraint system
    - hopper failure modes and designs which minimize pilot contact with chemicals
    - mechanisms which minimize damage due to wire strikes

- Subtask 3.7.2.0

  The evaluation of improved fire-proofing concepts would perform an examination of the following areas:

  - fuel tank design
  - cockpit isolation from flammables
  - protective clothing design

- Subtask 3.7.3.0

  The goal of the cockpit environmental control systems requirements effort would be to develop a safe, shirt-sleeve environment for the ag-pilot. This assumes that the pilot would not have to transit through a flame-filled or chemically contaminated area while escaping from his cockpit. Protective suit designs would be investigated for cases in which a shirt-sleeve environment either does not exist or is not desirable due to fire or chemical hazards.

- Subtask 3.7.4.0

  Part of this cockpit systems design task would be concerned with cockpit human factors design concepts. This effort would consider the following factors:

  - shapes, position, and force/displacement relationships for cockpit controls
  - seat design and positioning
  - visibility requirements
  - development of a real-time energy management calculator which computes aircraft take-off and climb performance.

● Task 3.8.0.0 - Aircraft Aerodynamics

Langley Research Center would have primary responsibility for this task. Wind-tunnel and flight tests would be conducted to evaluate thick airfoil applications, high-lift concepts, improved turning performance concepts, and stall prevention and avoidance concepts.

- Subtask 3.8.1.0

  New NASA low-speed thick airfoils would be evaluated for applications in agricultural aircraft design. The NASA LS (1)-0421 (21-percent thick) would be subjected to model tests and concurrent design studies. These would evaluate both aircraft performance and the use of large internal wing volumes for internal dispersal system ducting and for the storage of ag-chemicals.

- Subtask 3.8.2.0

  To meet take off and landing requirements of ag aircraft, high lift concepts would be evaluated on the new NASA low speed airfoils. Candidate concepts would include conventional and augmented leading and trailing edge high lift devices, as well as, boundary layer control concepts. Studies would be conducted to ascertain the feasibility of integrating the use of a high lift device with the optimal dispersal of agricultural materials in an aircraft's wake.

- Subtask 3.8.3.0

  The objectives of research on turning performance would be to improve aircraft productivity by reducing time through the application of high lift devices and specific airframe design. This work would be closely coupled with research on swath guidance techniques to allow maximum utilization of minimum turn radii.

- Subtask 3.8.4.0

  The evaluation of stall characteristics would be directed toward improvements in safety of aerial application operations. Stall preventive and stall avoidance concepts would be evaluated for extending the usable angle of attack range of agricultural aircraft.

3.2.4 Part 4.0.0.0 - Systems Demonstration

Throughout the program, requirements could arise for the development of hardware for the demonstration of technology resulting from many of the tasks outlined previously. Demonstration and full-scale development of subsystem or component technologies would precede major systems integration for demonstration of a concept with flight hardware. It is anticipated that such flight hardware could consist of modifications to an existing airframe incorporating results from research efforts in wake interactions (Task 3.1.0.0), dispersal systems (Task 3.2.0.0), airframe and dispersal systems materials (Task 3.5.0.0), propulsion systems (Task 3.6.0.0), and aircraft aerodynamics (Task 3.8.0.0).

The design, construction, and modification tasks (4.1.0.0, 4.2.0.0, and 4.3.0.0, respectively) would be largely grant and contracted efforts, while engineering and operational system evaluation (Task 4.4.0.0) would be conducted by NASA with participation by the agricultural aviation industry.

Systems demonstration activities would be the responsibility of each Center as required for their specific tasks.

Systems integration and demonstration would be the responsibility of Langley Research Center, with the support of Lewis Research Center and Wallops Flight Center as required.

4. MILESTONE SCHEDULE

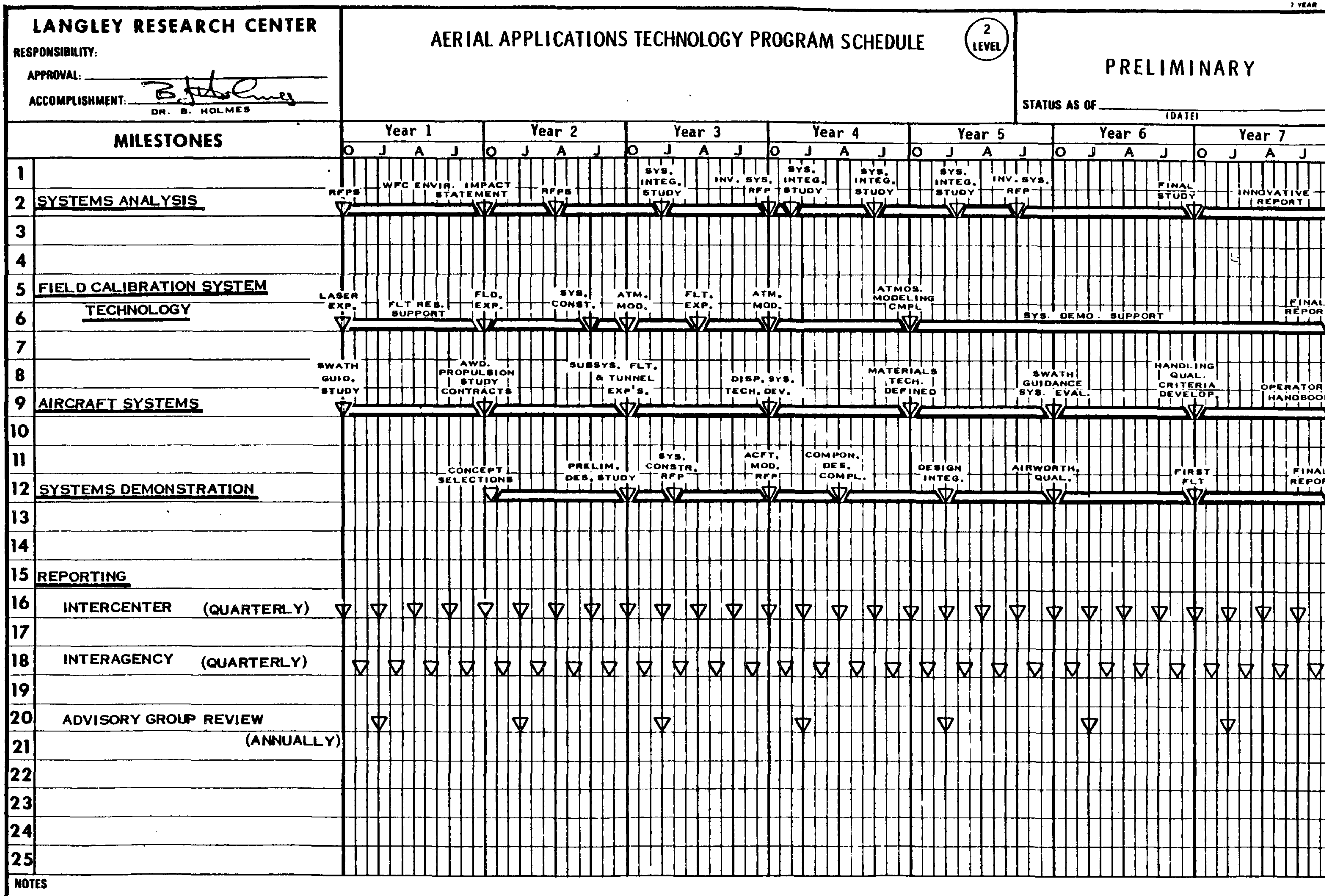


Figure 4.1- Level 2 Milestone Schedule.

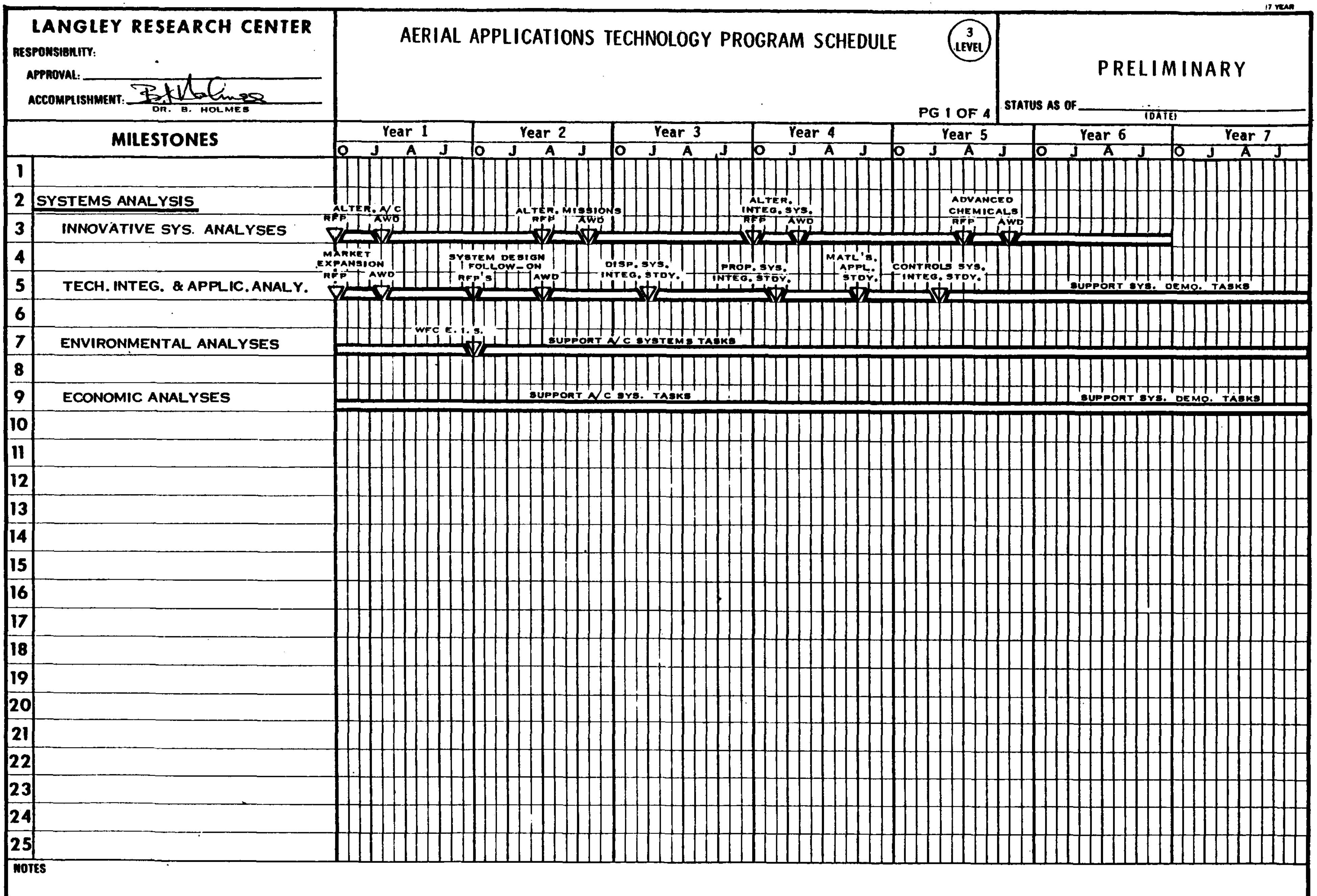


Figure 4.2- Level 3 Milestone Schedule.

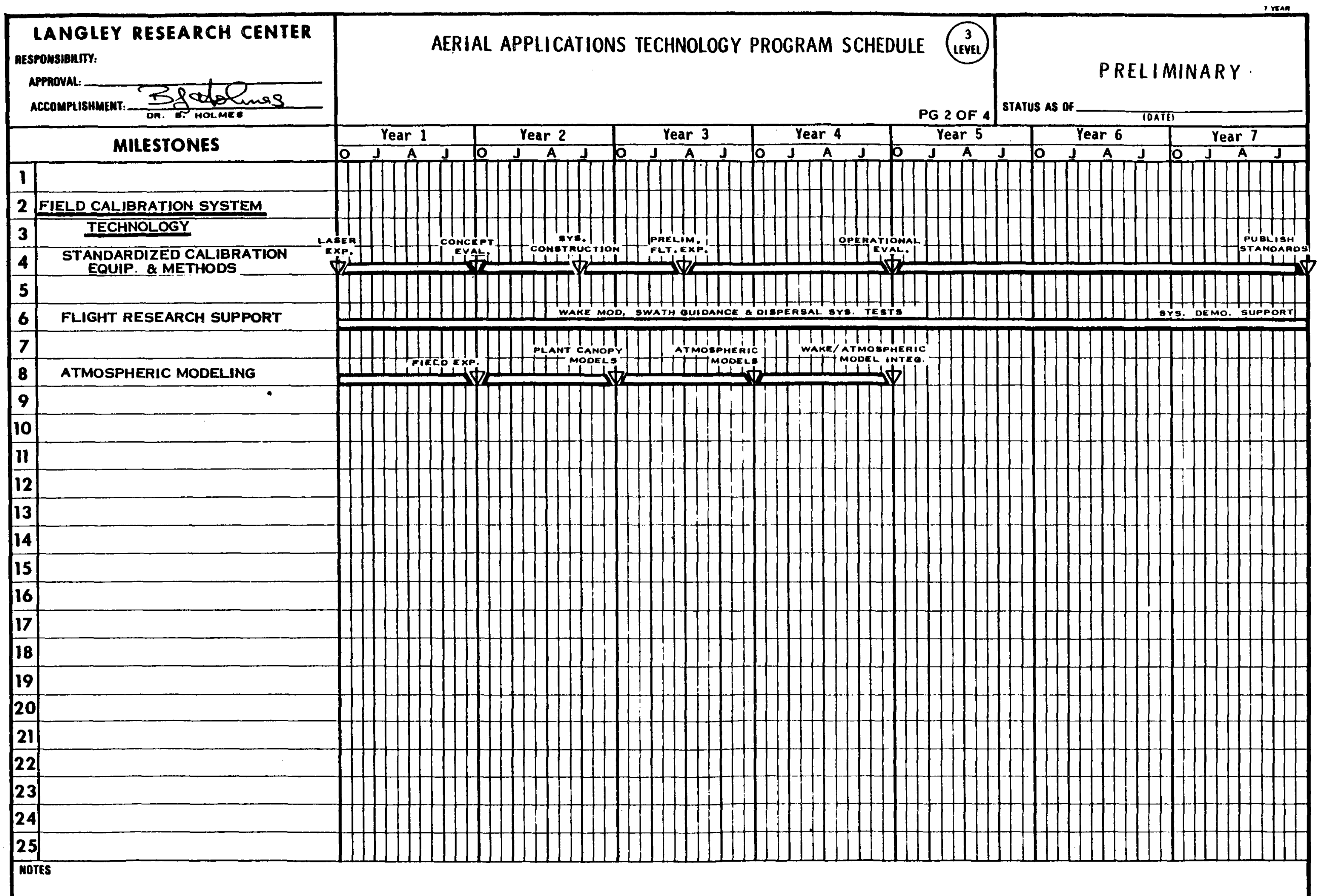


Figure 4.2- Level 3 Milestone Schedule (Continued).

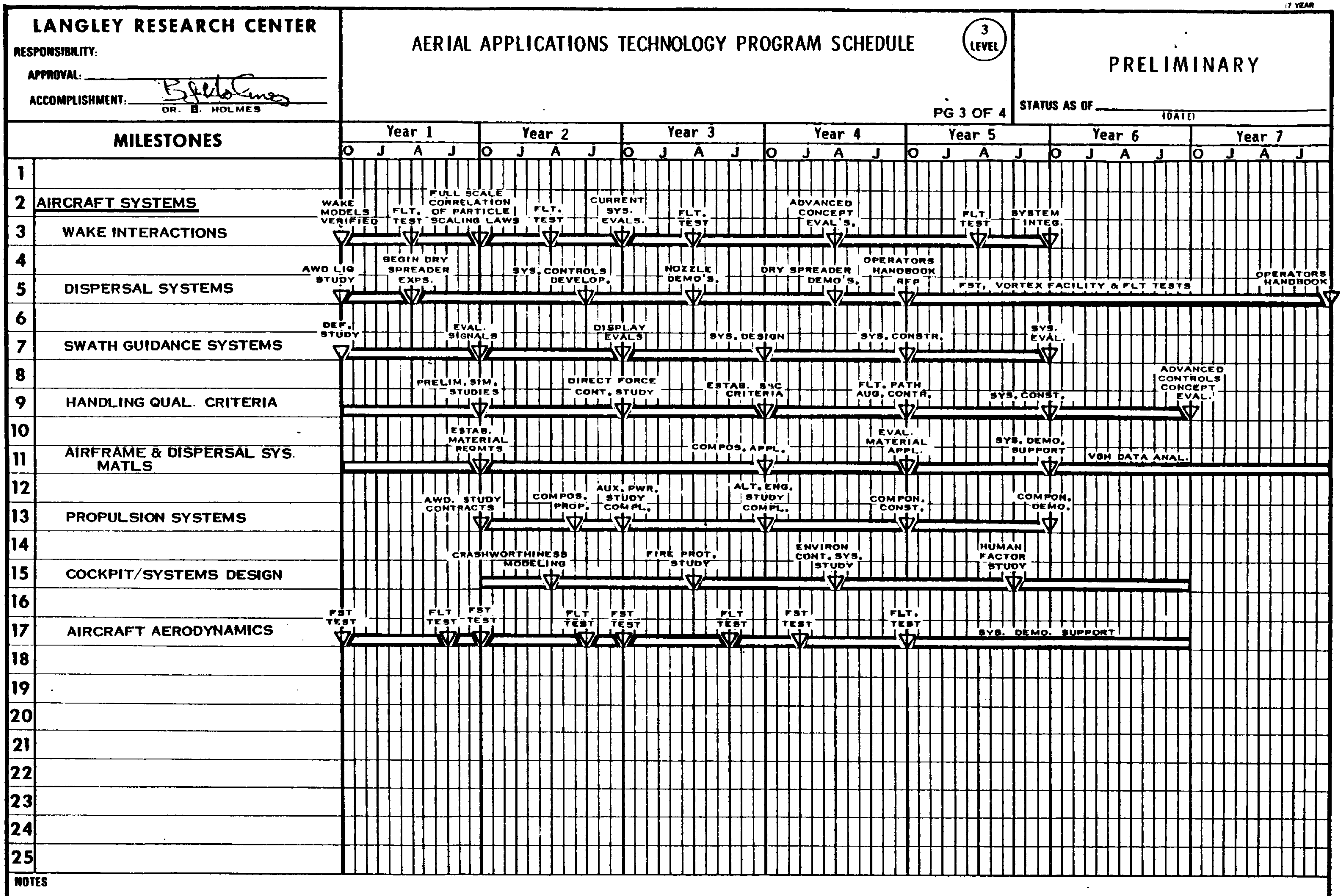


Figure 4.2- Level 3 Milestone Schedule (Continued).

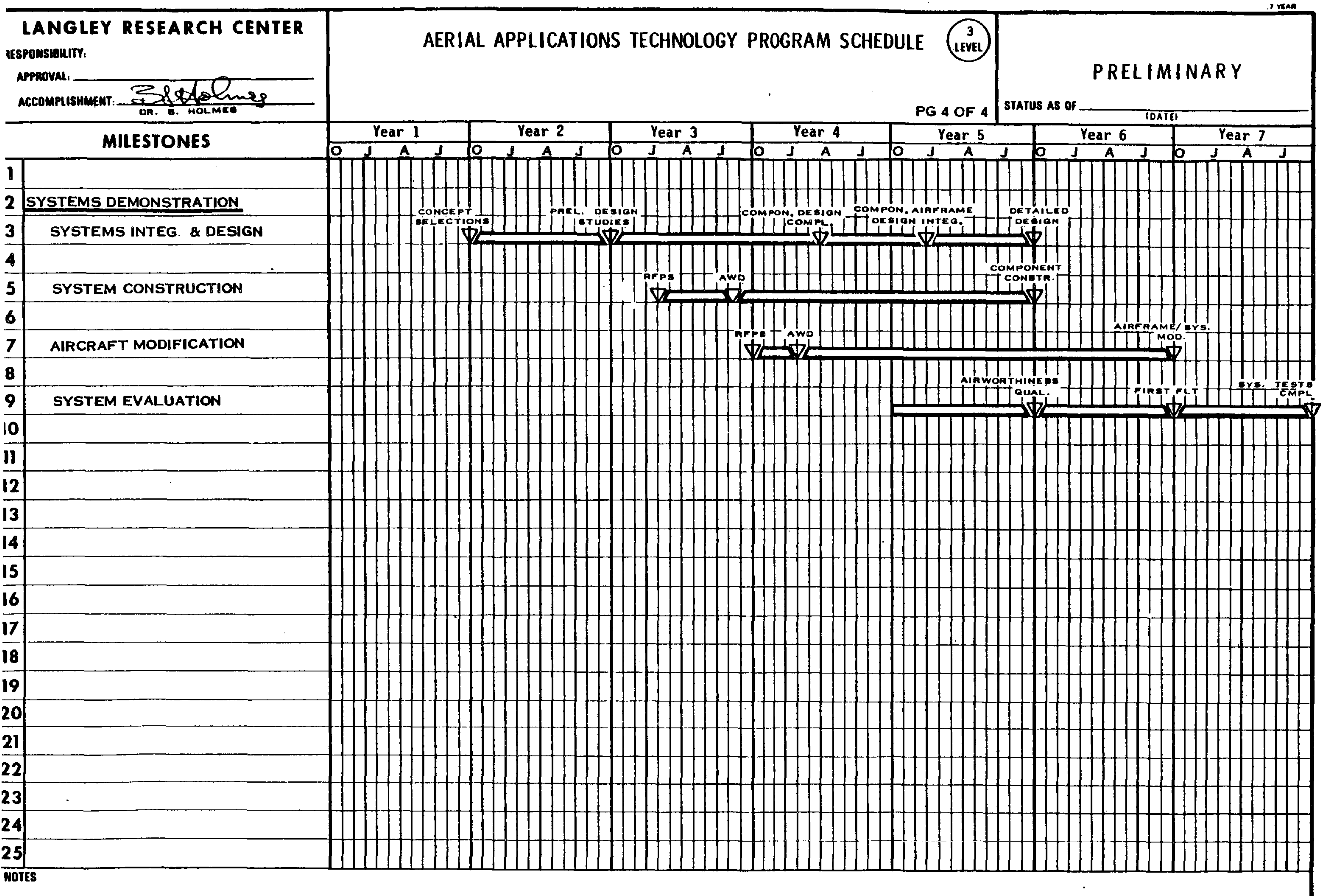


Figure 4.2- Level 3 Milestone Schedule (Concluded).

5. Resources

The Aerial Applications Technology Program would draw on the capabilities of three NASA centers. This section presents the funding requirements of the program. Table 5.1 summarizes the annual resource requirements. Figure 5.1 presents New Obligation Authority funding profiles by program part.

The resources estimated in the program plan were estimated by grass roots and/or analogous costing methods. This procedure was initiated at the task or subtask level.

Table 5.1

Program Annual Resources

Resources	Program Year							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Totals
$M	2.0	6.0	8.1	7.5	7.0	4.5	2.0	$ 37.1 M
CS M/Y	51.0	60.0	64.0	51.3	48.7	22.7	12.3	310.0 M/Y
Supp. M/Y	4.0	6.0	6.0	4.0	5.0	2.5	2.5	30.0

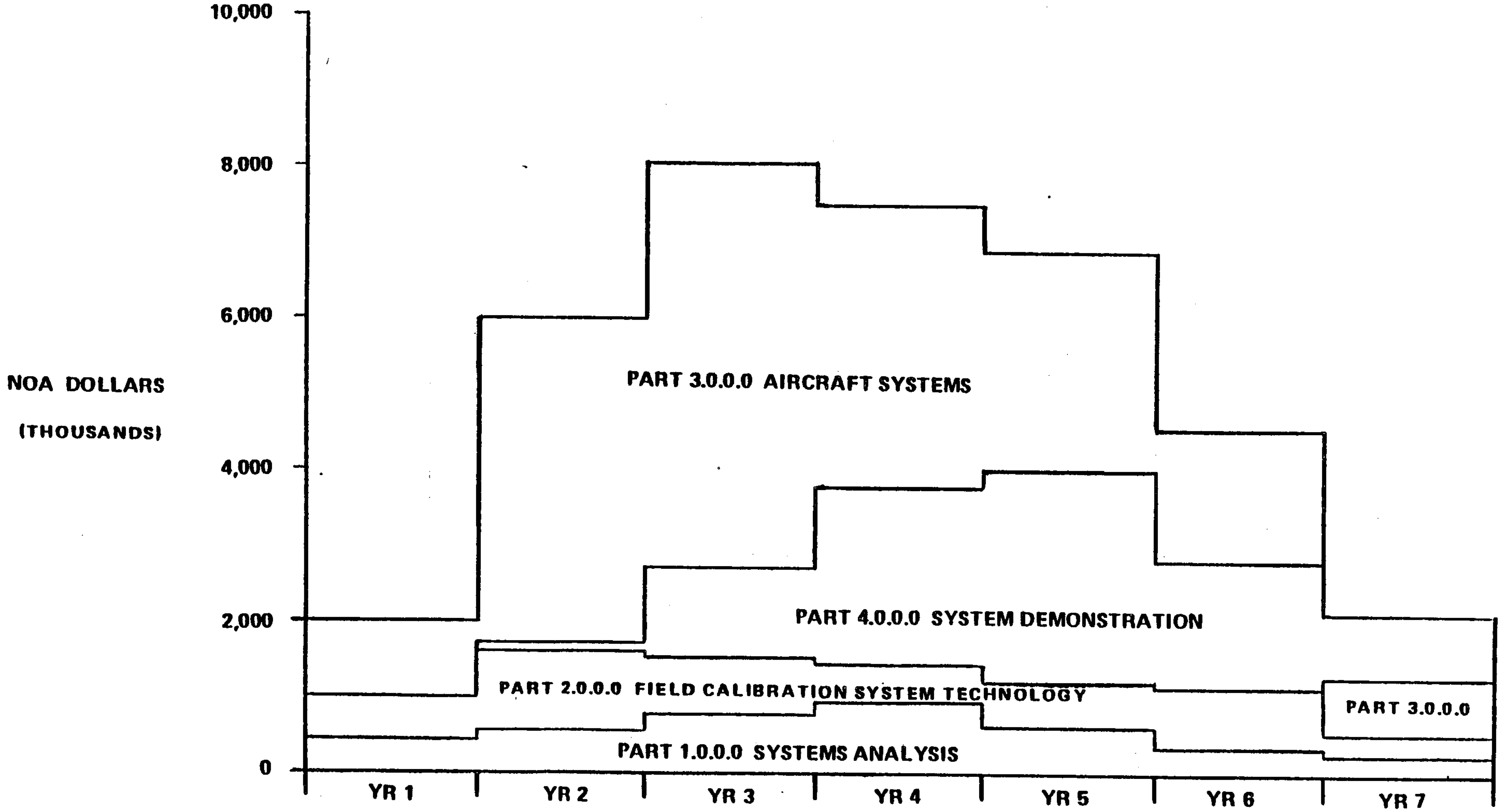


Figure 5.1 New Obligation Authority Funding Profile

6. ENVIRONMENTAL IMPACT

Based on an assessment of existing program plans, the net environmental impact of the Aerial Applications Technology Program is projected to be beneficial. The use of technology generated by this program could mean reduced waste in the application of agricultural materials and increased energy efficiency in the agricultural production system. These and other benefits which could accrue to the use of improved aerial applications systems in agriculture could have significant beneficial effects in the following environmental areas (from the National Environmental Policy Act):

- Air quality
- Water quality
- Fish and wildlife
- Noise
- Hazardous substances
- Pesticides
- Energy supply and natural resource development
- Soil and plant conservation and hydrology
- Land use and management.

Due to the nature of test programs planned at Wallops Flight Center further downstream in the program, an Environmental Impact Statement would be required to evaluate the impact of testing with agricultural chemicals on the facility and surrounding land. It is anticipated that early tests at Wallops would be performed with benign materials, but that perhaps as early as 1900, testing with actual chemicals would begin.

APPENDIX A

ECONOMIC BENEFITS

The National Science Foundation reports that an estimated 33.8 percent of worldwide crops are lost each year to various pests. The figures from parts of the world which do not have high-level pest control technology are even greater (see ref. 1 and Table 1). A significant reduction in any of these losses would have two effects: (1) significantly increase world supplies of food and fiber; (2) increase the net profit to the farmer and through him increase the economy.

In the United States, 20 percent of all pest treatment is by air; however, in some areas (e.g., California and parts of the South), as much as 50 percent of all applications are by air. A breakdown of agricultural aircraft by state is shown in Figure 1. Improvements in aerial application technology can stimulate the agricultural aviation industry resulting in increased productivity and in substantial savings to the farmer and ultimately, the consumer.

In this section the potential cash benefits that may result from improvements in aerial applications are discussed. Next, the non-quantifiable cash benefits of the program are examined and, finally, the non-cash benefits to the environment will be treated.

The potential benefit of improved aerial applications technology is illustrated using six crops: corn, cotton, wheat, rice, sorghum, and

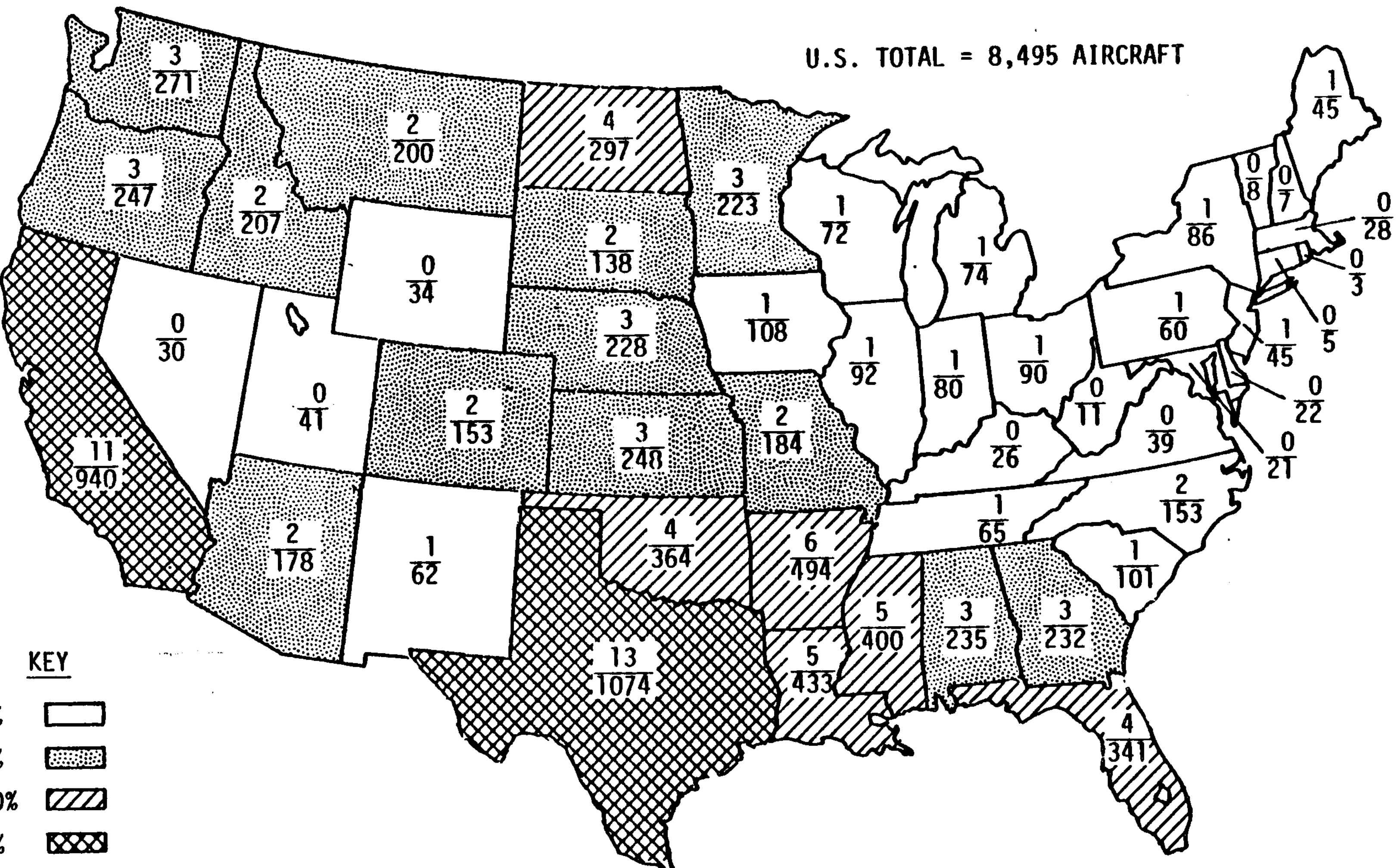
TABLE 1 - LOSSES OF POTENTIAL CROP PRODUCTION BY REGION

(from ref. 1)

REGION	ACTUAL VALUE $M	POTENTIAL VALUE $M	% LOSSES DUE TO			LOSS AS % POTENTIAL VALUE	VALUE-LOST PRODUCTION $M
REGION			INSECT PESTS	DISEASES	WEEDS		
NORTH AND CENTRAL AMERICA	24392	34229	9.4	11.3	8.0	28.7	9837
SOUTH AMERICA	9276	13837	10.0	15.2	7.8	33.0	4561
EUROPE	35842	47769	5.1	13.1	6.8	25.0	11927
AFRICA	10843	18578	13.0	12.9	15.7	41.6	7735
ASIA	35715	63005	20.7	11.3	11.3	43.3	27290
OCEANIA	1231	1707	7.0	12.6	8.3	27.9	476
USSR AND PEOPLE'S REPUBLIC OF CHINA	20140	28661	10.5	9.1	10.1	29.7	8521
WORLDWIDE	137439	207786	12.3	11.8	9.7	33.8	70347

NUMBER OF AGRICULTURAL AIRCRAFT BY STATE

U.S. TOTAL = 8,495 AIRCRAFT



KEY

0-1%

2-3%

4-10%

11+%

X/X — % U.S. (0 INDICATES <1%) / NUMBER OF AIRCRAFT

Source: 1976 FAA Records
Single Engine Fixed Wing
and Rotary Wing Aircraft.

FIGURE 1

soy beans. These crops were selected because, in 1976, they comprised 72 percent of total U.S. harvest (ref. 2). The benefits to the industry of increased ferry speed and reduced turn time are calculated. Other potential benefits can be expected from improvement in droplet size control, increased swath width, and improvements in swath guidance systems.

Ferry Speed. An increase in average ferry speeds is a realistic expectation from this program. Table 2 illustrates the potential savings to the industry of a 5 mile per hour increase. The reader is cautioned that due to the possible overlap, the savings indicated in the following graphs should not be treated as necessarily additive. The figures in Table 2 were arrived at by combining 1971 USDA cost per acre figures (adjusted for inflation), 1971 USDA figures for percentages of farmers using custom application, 1977 figures for number of acres in production, and the data from a 1977 NASA contract study of the ratio of ferry speed to savings (Figure 2). The table is rough because of the combining of figures. The figures are conservative because the inflation rate does not reflect the true increase in the cost of custom application service.

Turn Time Reduction. The benefits of turn time reduction are calculated in the same manner as the ferry speed increase using a data base from the same sources (Figure 3). Table 3 approximates the potential benefits to be derived from a 10-second reduction in turn time.

A 10-second reduction in turn time is a one-third saving over the current estimated 30-second turn time. The potential savings to the industry for crops such as rice, where 100 percent of those applying pesticides do so by air, is large.

Other Cash Benefits. The aerial applications technology program calls for research into droplet size control, improved uniformity of application, and improved swath guidance technology.

There is an ideal droplet size for each chemical for each pest in each crop. This size is determined by the purpose of the chemical. For example, herbicides are systemic chemicals. As such, they need not be dispersed in a fine mist. The ideal size would accomplish the task while minimizing volatization. The benefits of reduced volatizations are reductions in air pollution

TABLE 2 - POTENTIAL SAVINGS THROUGH IMPROVED FERRY SPEED OF 5 MILES PER HOUR FOR 6 SIX CROPS USING SPRAYS

(Material Cost Not Included)

CROP	ACRES TREATED BY AIR (1000's)/1.	COST PER ACRE TO FARMER/2.	TOTAL COSTS	% SAVINGS BY 5 MILE INCREASE	SAVINGS PER ACRE	ANNUAL SAVINGS TO INDUSTRY/3.
COTTON	4780	$4.08	$19,500,000	3.6	15.0¢	$ 700,000
RICE	2275	2.63	5,983,000	10.2	26.8	610,000
WHEAT	7675	1.59	12,203,000	3.3	5.2	400,000
CORN	1877	2.34	4,392,000	6.3	14.7	275,000
SOY BEANS	3200	1.88	6,016,000	3.3	6.2	200,000
SORGHUM	4641	1.98	9,189,000	1.6	3.2	150,000
					TOTAL	$2,335,000

1. Calculated on USDA 1971 figures of percent of farmers using custom application as a function of 1976 acres planted (ref. 4).

2. Calculated on USDA 1971 costs adjusted to 7 percent annual inflation rate (ref. 5).

3. July 1977 Econ report, NASA Contract No. NASW-2580.

COST SAVINGS FROM INCREASED FERRY SPEED FOR SIX CROPS BY CROP

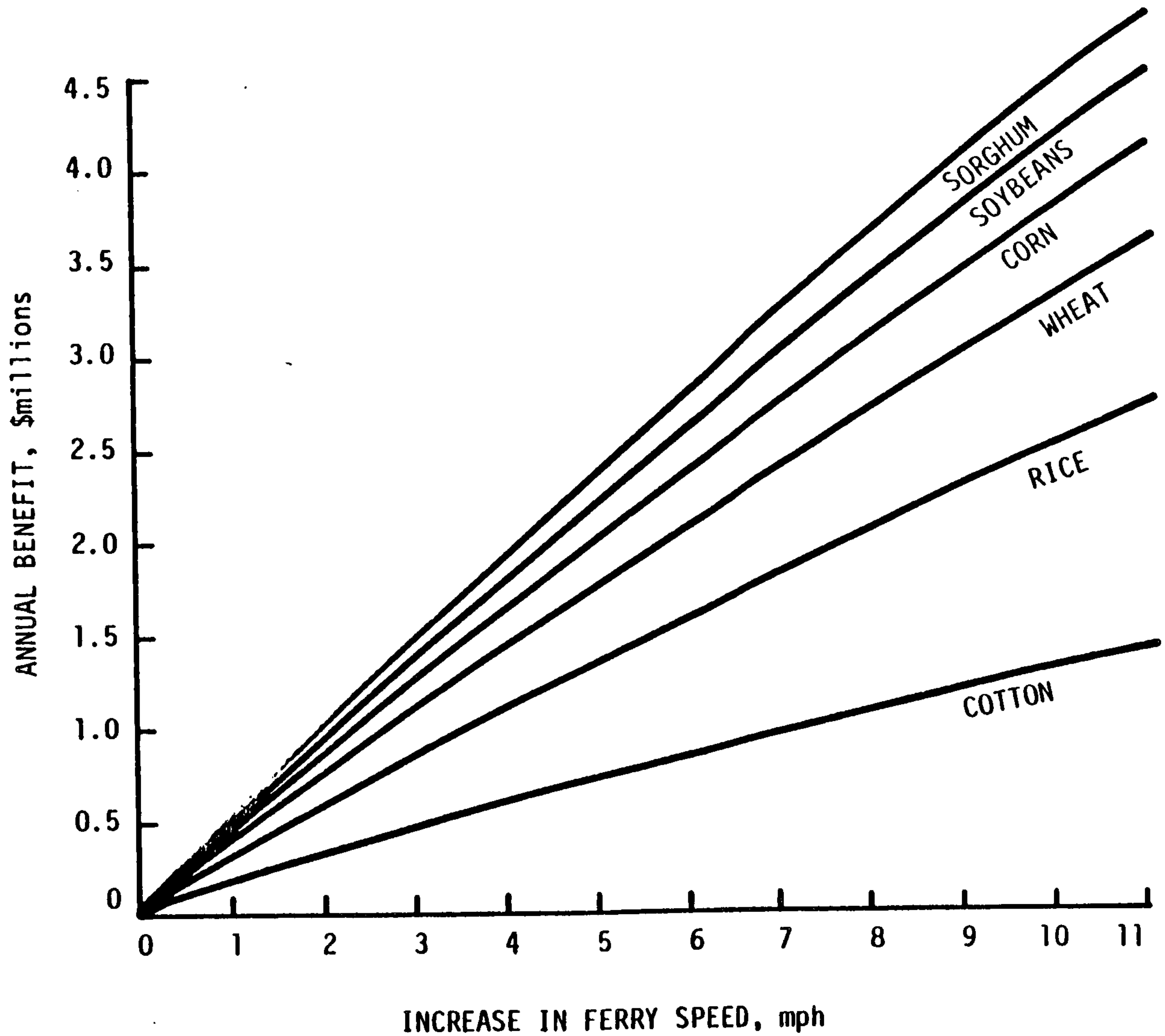


FIGURE 2

COST SAVINGS FROM REDUCED TURN TIME ON SIX CROPS

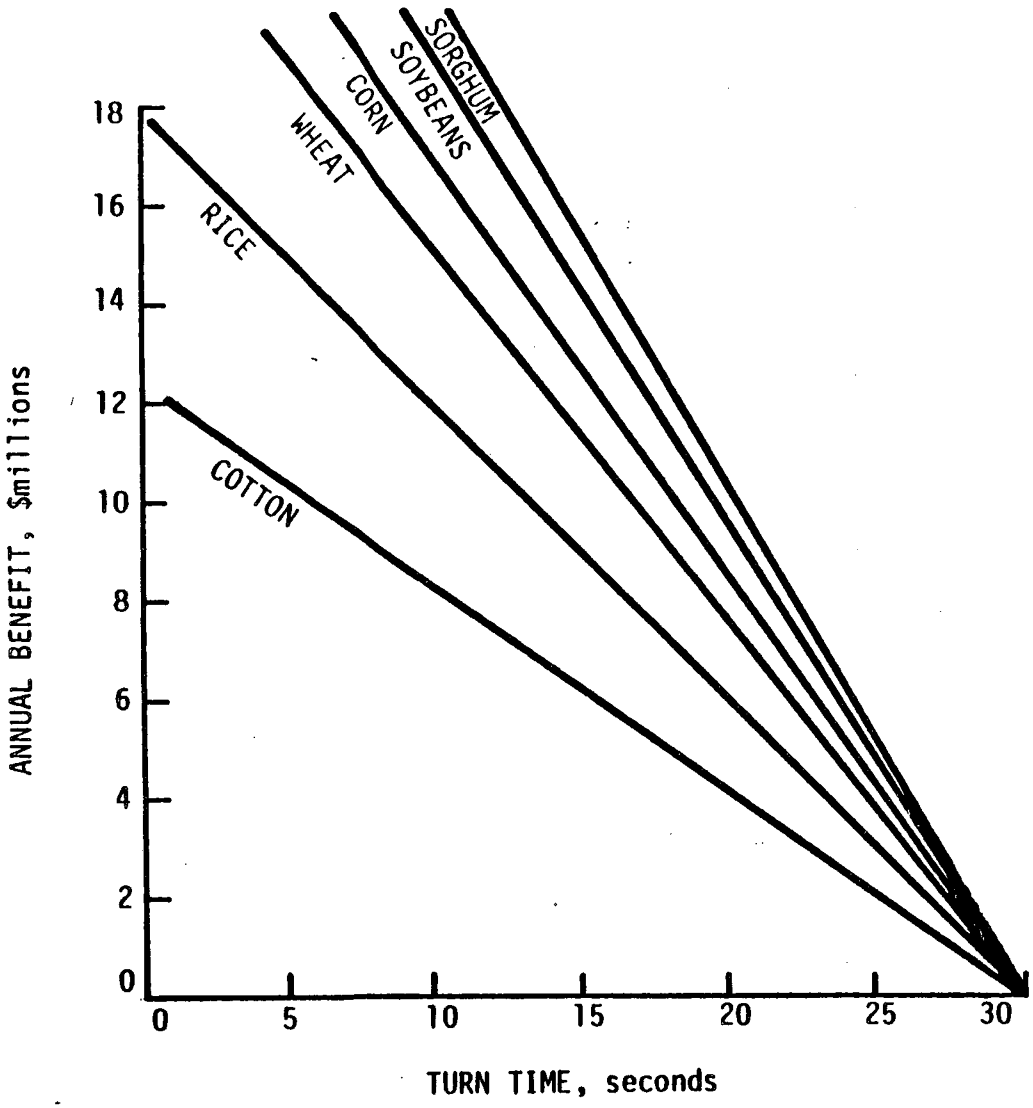


FIGURE 3

NOTE: PRESENT AVERAGE TURN TIME IS 30 SECONDS

TABLE 3 - POTENTIAL SAVINGS THROUGH REDUCED TURN TIME
USING A 10 SECOND REDUCTION FIGURE FOR 6 CROPS
(Material Cost Not Included)

CROP	ACRES TREATED BY AIR (1000's)/1.	COST PER ACRE TO FARMER/2.	TOTAL COSTS	% SAVINGS BY 10 SECOND REDUCTION	SAVINGS PER ACRE	ANNUAL SAVINGS TO INDUSTRY/3.
COTTON	4780	$4.08	$19,500,000	22	.90¢	$ 4,300,000
RICE	2275	2.63	5,983,000	30	.79	1,800,000
WHEAT	7675	1.59	12,203,000	14	.22	1,700,000
CORN	1877	2.34	4,392,000	25	.59	1,100,000
SOY BEANS	3200	1.88	6,016,000	16	.30	960,000
SORGHUM	4641	1.98	9,189,000	8	.16	740,000
					TOTAL	$10,600,000

1. Calculated on USDA 1971 figures of percent of farmers using custom application as a function of 1976 acreage.

2. Calculated on USDA 1971 costs adjusted to 7% annual inflation rate

3. July 1977 Econ report, NASA Contract No. NASW-2580.

and in the total amount of chemical applied. On the other hand, insecticides and fungicides are applied in much smaller droplet size in order to cover the foliage. These chemicals are currently applied under a variety of conditions using a variety of nozzles without concrete knowledge of the ideal droplet size. Possession of this knowledge would also reduce chemical losses to volatization and would obviate excessive application rates (Figure 4).

Improving the uniformity of application results in increased productivity through improved application efficiency. Closely related to uniformity is swath guidance technology. Currently, a flagman is frequently used to guide the application. Alternative swath guidance systems in the aircraft could eliminate the flagman which would reduce the cost of application and eliminate an industrial safety hazard. Figure 5 illustrates the trends in benefits from alternative swath guidance technology.

<u>Secondary Economic Benefits</u>. The predicted savings in Tables 2 and 3 are based upon 1971 use levels of custom application.

As more cost effective air technology becomes available, the potential number of farmers able to utilize the service will increase. In 1971, only a small portion of the farmers sampled by the USDA utilized custom application, as indicated in the following table.

TABLE 4

PERCENTAGE OF FARMERS USING PESTICIDE AND CUSTOM PESTICIDES IN 1971, FOR SIX CROPS

	FARMERS REPORTING PESTICIDE USE*	FARMERS REPORTING CUSTOM PESTICIDE SERVICE**
COTTON	86	51
RICE	91	100
WHEAT	23	47
CORN	68	33
SOY BEANS	63	22
SORGHUM	52	53

* As a percentage of total farms growing the crop
** As a percentage of total farms using pesticides

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON SIX CROPS

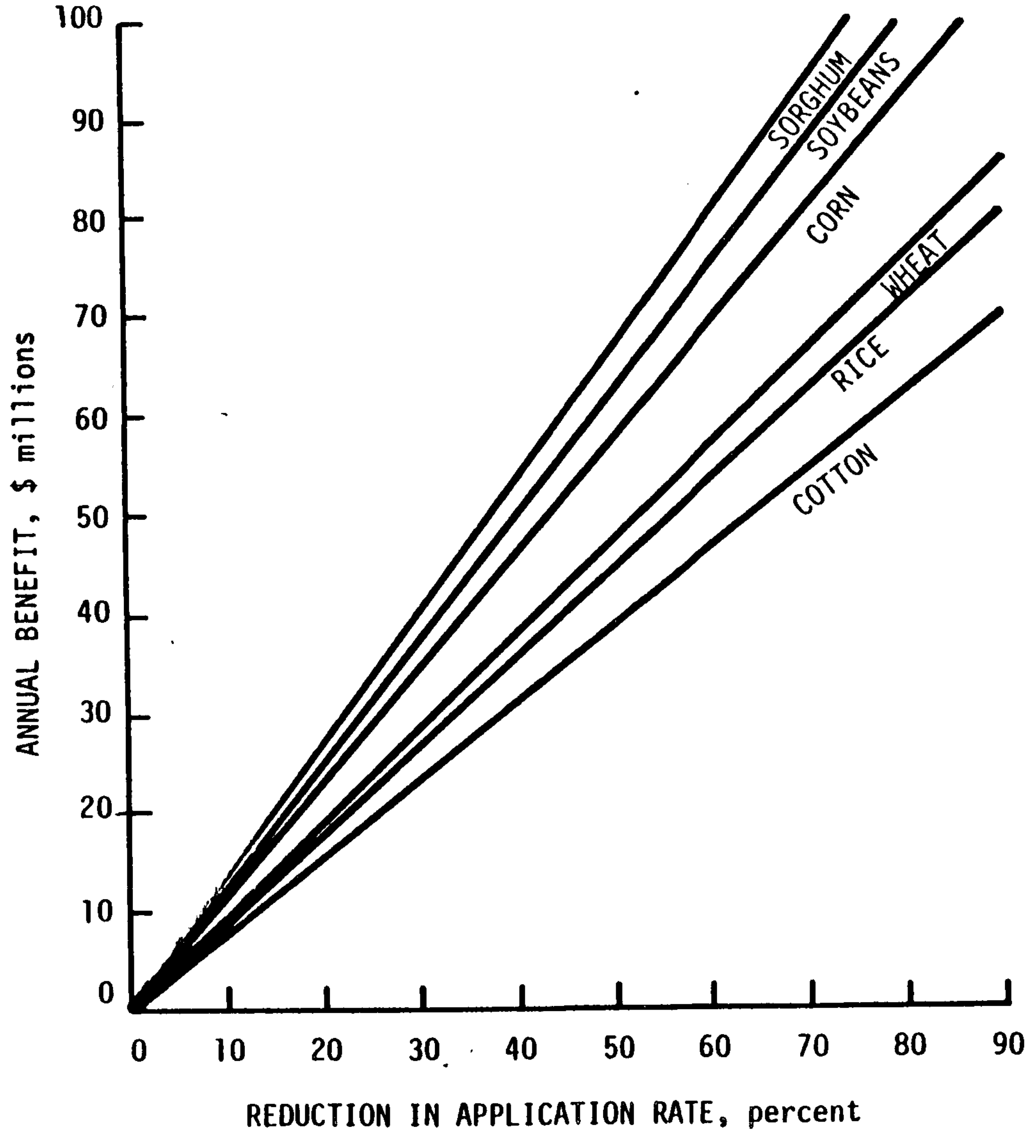


FIGURE 4

COST SAVINGS FROM REDUCTION IN USE OF FLAGMEN FOR SIX CROPS

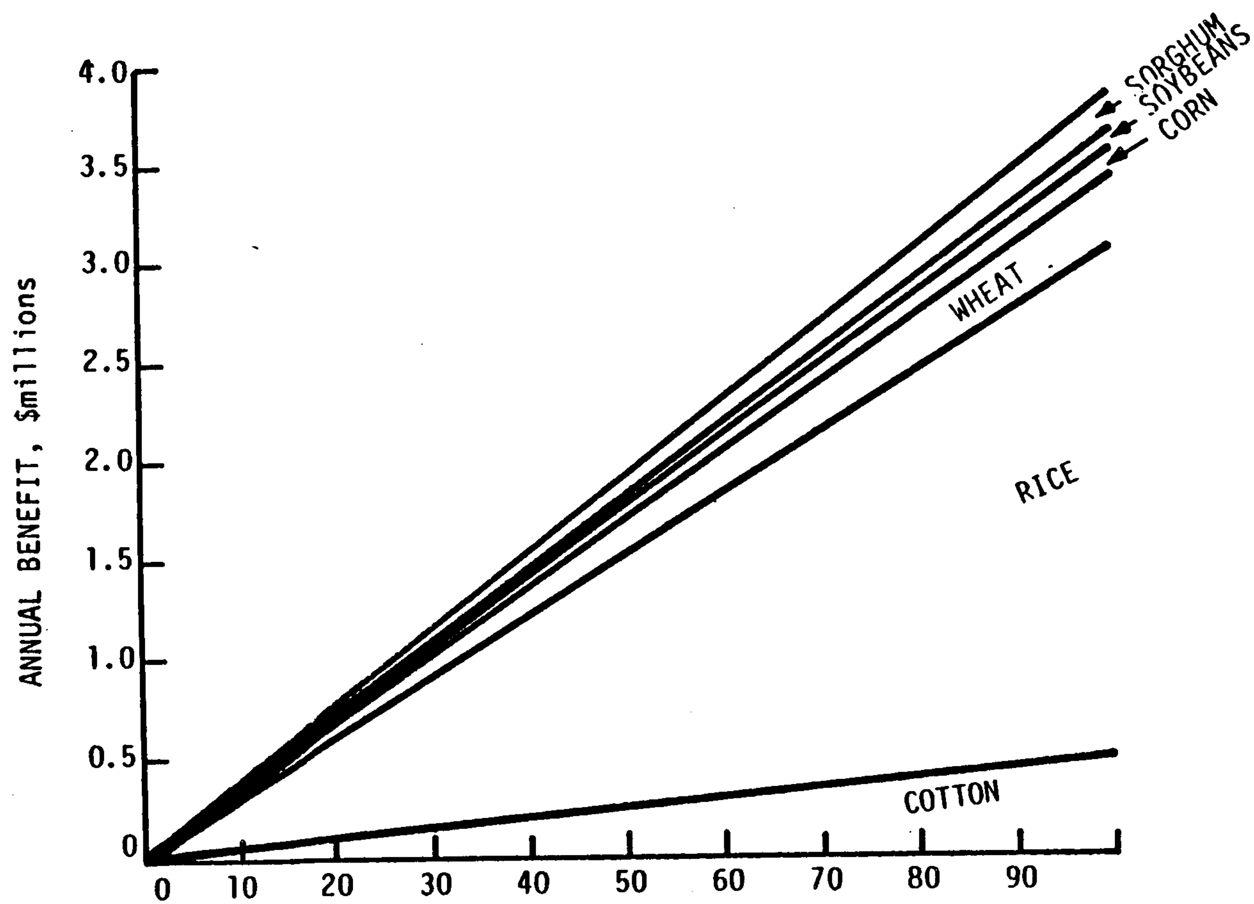


FIGURE 5

The greatest potential (acreage) increase in farmers using custom pesticide service is among wheat farmers. Potential for much growth exists in five of the six crops - only rice has reached its potential.

Reasonably priced custom application would free the capital that the farmer currently expends on the purchase, maintenance, and operating of ground equipment. Finally, increased use of aerial application would increase the demand for both aerial operators and aircraft, thereby stimulating two industries.

Non-cash Benefits. In 1972, the Council on Environmental Quality issued a document entitled, "Integrated Pest Management" (ref. 8). The document called for alternative means of pest control including biological control, crop rotation, and the more intelligent use of pesticides.

In the past, farmers did what is known as "insurance spraying." The logic is to treat for the pest whether one has it or not to insure its control. Frequently, such applications have been ill timed and often unnecessary. Such uninformed treatment is expensive and environmentally harmful. The environment is harmed by air pollution through volatization and water pollution by the run-off of excess chemicals (ref. 9).

Under a system of integrated pest management, crops are closely monitored to determine if and when pesticide use is justified. The key to such a system is timeliness. Timely application most often means aerial applications. Research to improve aerial applications technology can lead to optimum utilization of the integrated pest management concept.

Conclusions.

- Annual benefits illustrated from ferry speed and turn time improvements are significant. These represent only two of several probable program results.
- Benefits which accrue due to improvements in droplet size control, swath uniformity and swath guidance technology are not readily quantifiable. However, their benefits are substantial.
- The ultimate benefits from the technology generated by the aerial applications technology program go to the consumer.

REFERENCES

1. Glass, Edward H.: Research Needs on Pesticides and Related Problems for Increased Food Supplies. A Report to the National Science Foundation, Feb. 1976, p.1.

2. Ibid., p.4.

3. Crop Reporting Board, USDA. Annual Crop Summary. Jan. 1977, pp. A4 and A5.

4. USDA. Farmers Expenditures for Custom Pesticide Services. Economic Report No. 314, p.8.

5. Ibid., p.14.

6. Econ., Inc. The Benefits of Improved Technologies in Agricultural Aviation. Prepared under NASA Contract NASW - 2580, July 1977.

7. Farmers Expenditures for Custom Application. p.8.

8. Council on Environmental Quality. Integrated Pest Management. Nov. 1972. U.S. Government Printing Office, Stock No. 4111-0010.

9. For a complete discussion of these hazards, see: Gorakis, P. A. and Sricas, A. G. The Presence and Cycling of Pesticides in the Environment; in Gunther and Gunther eds. Residue Reviews, (New York, Springer Verlag, 1974) pp. 69-89.

APPENDIX B

AGRICULTURAL AVIATION USER REQUIREMENT PRIORITIES

The information presented in this appendix is extracted and edited from NASA Contractor Report 145215, entitled _Agricultural Aviation User Requirement Priorities_, by Actuarial Research Corporation, May 1977.

SUMMARY OF RESULTS

The results of a research project to develop agricultural aviation user requirement priorities are reported herein. The raw data used in the project were obtained from the National Agricultural Aviation Association. A specially-configured poll, developed by the Actuarial Research Corporation, was used to solicit responses from Association members and others. The polling was conducted by NAAA representatives at a series of 15 state and regional NAAA conventions during the period January to March 1977. Additional questionnaires were mailed to NAAA members in those states not holding annual meetings.

ARC was instructed to focus its examination of the problem areas solely on the fixed-wing segment of the industry; therefore, the polling format was so oriented. Returns indicating the respondents to be operators and/or pilots of helicopters only were purposefully removed from consideration. Respondents indicating both fixed-wing and helicopter backgrounds were included in the data pool. A total of 625 responses were analyzed. Four hundred eighty-four responses were received from the NAAA conventions; 771 questionnaires were mailed, and 149 were returned (8 questionnaires were not used, giving a total of 141 from the mailing).

Since the polling was conducted by the NAAA, the opportunity for screening the respondents was beyond the control of ARC. From the background information in the descriptive portion of the questionnaire, however, it was possible to review the qualifications and summarize the experience of the respondents.

One important indicator of qualification is that of the occupational categories of the respondents. Table 1 summarizes this issue. Figure 1 summarizes the overall agricultural aviation experience in years of the respondents; they average 13.8 years of experience. The multimodal distribution can be attributed to the probable natural tendancy of the respondent to recall such information on a convenient (5, 10, 15, etc., year) basis.

Figure 2 depicts the distribution of agricultural flight hours for those respondents who are or have been aviators—some 95.7 percent of the total. The average agricultural flight hours are 5,250 per person. The average <u>total</u> for the group is 8,055 hours per person, which may be considered as a significant indicator of experience in itself.

Two additional pieces of general information were extracted from the biographical portion of the questionnaire. One body of data describes the percentage of respondents servicing a particular crop. This information is reflected in Table 2. (Note that percentages do not total 100 since a respondent can service more than one crop.)

TABLE 1

OCCUPATIONAL CATEGORIZATION OF RESPONDENTS

Category	Number of Respondents	Percentage of Total
Owner-Operator[1]/Pilot	429	69
Pilot only	109	17
Owner-Operator/Pilot/Allied Industry[2]	52	8
Owner-Operator (non-pilot)	22	4
Pilot/Allied Industry	8	-
Owner-Operator/Allied Industry	3	-
Other[3]	2	-
Total	625	

[1] The owner-operator is defined as the owner-entrepreneur and/or manager of an aerial application service.

[2] An allied industry member is a supplier of chemicals, equipment, materials, and/or services (e.g., aircraft maintenance, etc.).

[3] "Others" refers to respondents who failed to indicate a category, but included sufficient additional information to permit retention.

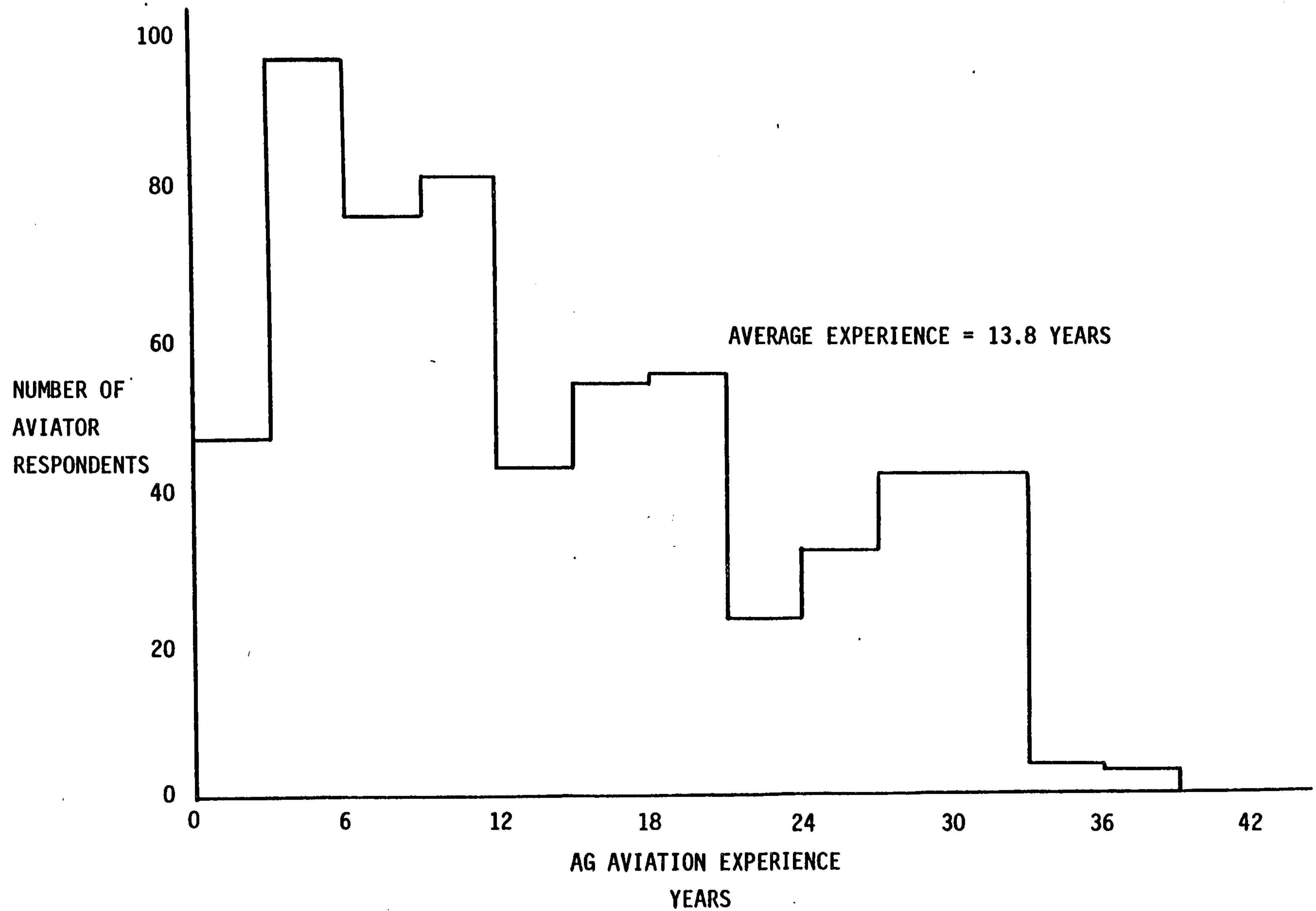


FIGURE 1. DISTRIBUTION OF RESPONDENTS' EXPERIENCE IN AGRICULTURAL AVIATION

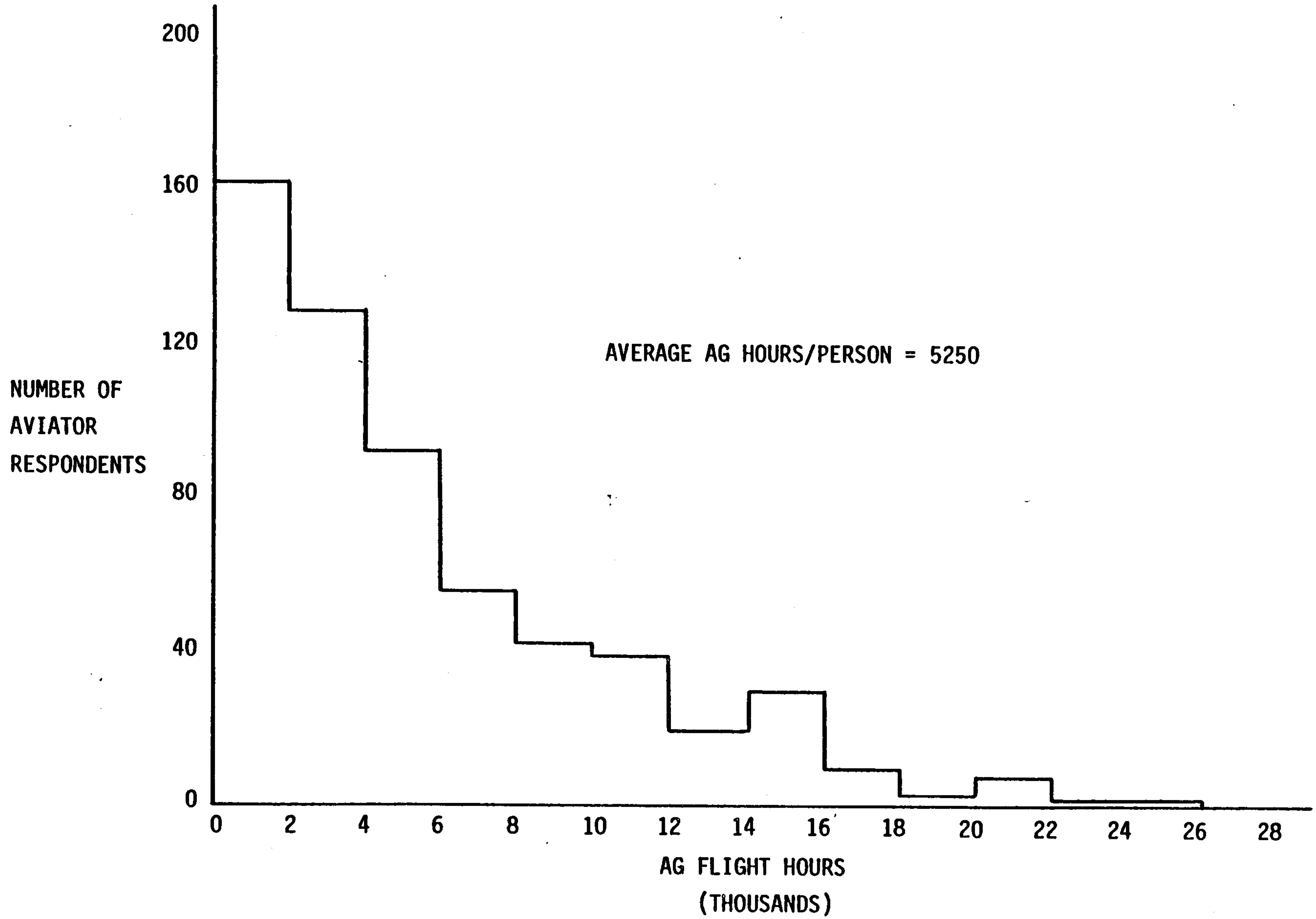


FIGURE 2. DISTRIBUTION OF RESPONDENTS' AGRICULTURAL FLIGHT HOURS

TABLE 2

DISTRIBUTION OF CROP SERVICING
(Percentages of Respondents)

Crop	%	Crop	%
Alfalfa, clover	43	Grapes	
Berries	4	Milo, sorghum	45
Citrus orchards	6	Range land	30
Corn, field	59	Rice	16
Corn, sweet	18	Soybeans	55
Cotton	44	Sugar cane	6
Forests (wood products)	10	Tobacco	9
Fruit orchards	16	Vegetables	27
Grain (wheat, oats, rye, barley, etc.)	77	Other	19

The other body of information as shown in Table 3 indicates the percentage of respondents who perform other types of services.

TABLE 3

OTHER SERVICES PERFORMED
(Percentages of Respondents)

Service	%
Pest control (non-crop)	28
Fire fighting:	
Water	4
Chemical	3
Aerial seeding	80
Night Operations	15
Rights-of-way (herbicides)	17
Other	12

Note from Table 3 that 80 percent of the applicators engage in aerial seeding operations. Pest control (non-crop) refers to the application of insecticides for general infestations such as fire ants and gypsy moths.

With respect to the type of dispensing, only five respondents indicated almost exclusive (i.e., 90 to 100 percent) specialization in dry materials wet, or liquid, application.

The primary product of the poll is the specification of seriousness as determined by the respondnets for some 41 selected agricultural aviation problem areas for daytime operations with fixed-wing aircraft (see summary in Table 4.) Figure 3 graphically represents the information contained in Table 4, with the problems being arrayed in descending order of "seriousness." The scale of weights forms the ordinate axis.[1]

The weighting factors are now related to each other in ratio form. For example, "drift" (item number 22) with a weight of 6.6 has been judged by the respondents to be 2.2 times more serious than, for example, "accumulation of dust and chemicals on windscreen" (item 31), weighted at 3.0.

It should be mentioned that drift is a problem resulting from a number of separate phenomena such as aerodynamic interference, boom location, droplet size, wing tip vortices, atmospheric and chemical parameters, etc. The owner/operators and pilots, however, are primarily concerned with only the net effects on their operations. This perception was made abundantly clear during the interviews leading to the development of the polling format. Hence, the term "drift" was used in lieu of the more precise, but less communicative, underlying technical causes of the problem.

The lowest ranked item (number 18, stall warning) should be interpreted as being only the least significant of the problem areas presented. This statement does not intend to preclude the existence of lesser problems. It must be remembered that all weights are relative, and as such the value of any weighting factors as an <u>absolute</u> is meaningless.

Figure 4 depicts the concept whereby the problems have been grouped in five identifiable categories. The weights for each item in a group may then be added together to form a "package value." The relative seriousness of the packages can then be assessed (see Table 5).

Although not necessarily an accurate observation, it may be argued that the package with the greatest number of component problems would become the most heavily weighted. To accommodate this condition, the concept of "average seriousness" is introduced. Average seriousness is merely the total seriousness divided by the number of components within the group.

The concept of average seriousness changes the significance of problem assessment. Note in Figure 4 that while the propulsion group has the lowest total seriousness weighting, the relative average seriousness is the highest. Generic packaging, therefore, should become part of the planner's assessment process.

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[1] Although retained for relative ranking purposes, the reader is cautioned that any finite significance in the first decimal place cannot be empirically established. In fact, each number could be rounded to the nearest whole or half number with little loss in generality or practicality.

TABLE 4

PROBLEM AREA WEIGHTS BASED ON ALL RESPONDENTS

Weight	No.	Item
2.4	1.	"In-the-field" repair and service of A/C
4.4	2.	Length of engine and accessory time-between-overhaul (TBO)
5.7	3.	Engine reliability
1.9	4.	"Wash-down" of A/C, inside and out
2.6	5.	Corrosion inspection and control
2.8	6.	Availability of replacement A/C engine
2.0	7.	"In-the-field" repair and service of dispersal systems
2.1	8.	"Flush-out" of dispersal system
2.3	9.	"Change-over" detoxification
3.0	10.	Ground handling of payload--proportioning, mixing, transfer, weighing, speed of operation
3.8	11.	Protecting ground crew from toxic materials
2.5	12.	Adjusting dispersal systems to meet new application requirements
2.0	13.	Rough-terrain TO and landing capability of the A/C
3.9	14.	Short take-off and landing capability of the A/C
1.8	15.	Cruise speed
2.9	16.	Climb-out/dive-in capability of the A/C
3.0	17.	Steep, short-radius turn capability of the A/C
1.0	18.	Stall warning
2.7	19.	Swath guidance
2.0	20.	Monitoring of individual nozzles/gates in flight
2.4	21.	Monitoring flow rate
6.6	22.	Drift
4.2	23.	Uniform dispersal pattern--providing even lateral (side to side) distribution in a swath
1.6	24.	Selecting dispenser turn-on/off points
2.4	25.	Effects of varying ground speed on dispersal
2.3	26.	Confirming uniformity and concentration of application post flight
3.3	27.	Determining uniformity of coverage and dosage of application during flight
5.0	28.	Capability of cockpit area to survive a crash
4.4	29.	Fire prevention and protection
1.7	30.	Maintaining A/C control during dump
3.0	31.	The accumulation of dust and chemicals on windscreen
3.0	32.	Cockpit visibility (unobstructed view)
2.7	33.	Location and design of cockpit flight and emergency controls
2.3	34.	Stick force effort during maneuvers
1.6	35.	Cockpit comfort
5.4	36.	Protecting pilot from toxic substances
1.6	37.	Mid-air collisions
3.0	38.	Ground obstacle detection and avoidance
2.5	39.	Fuel consumption
2.6	40.	External A/C noise
2.9	41.	Flexibility of A/C to meet different AG requirements

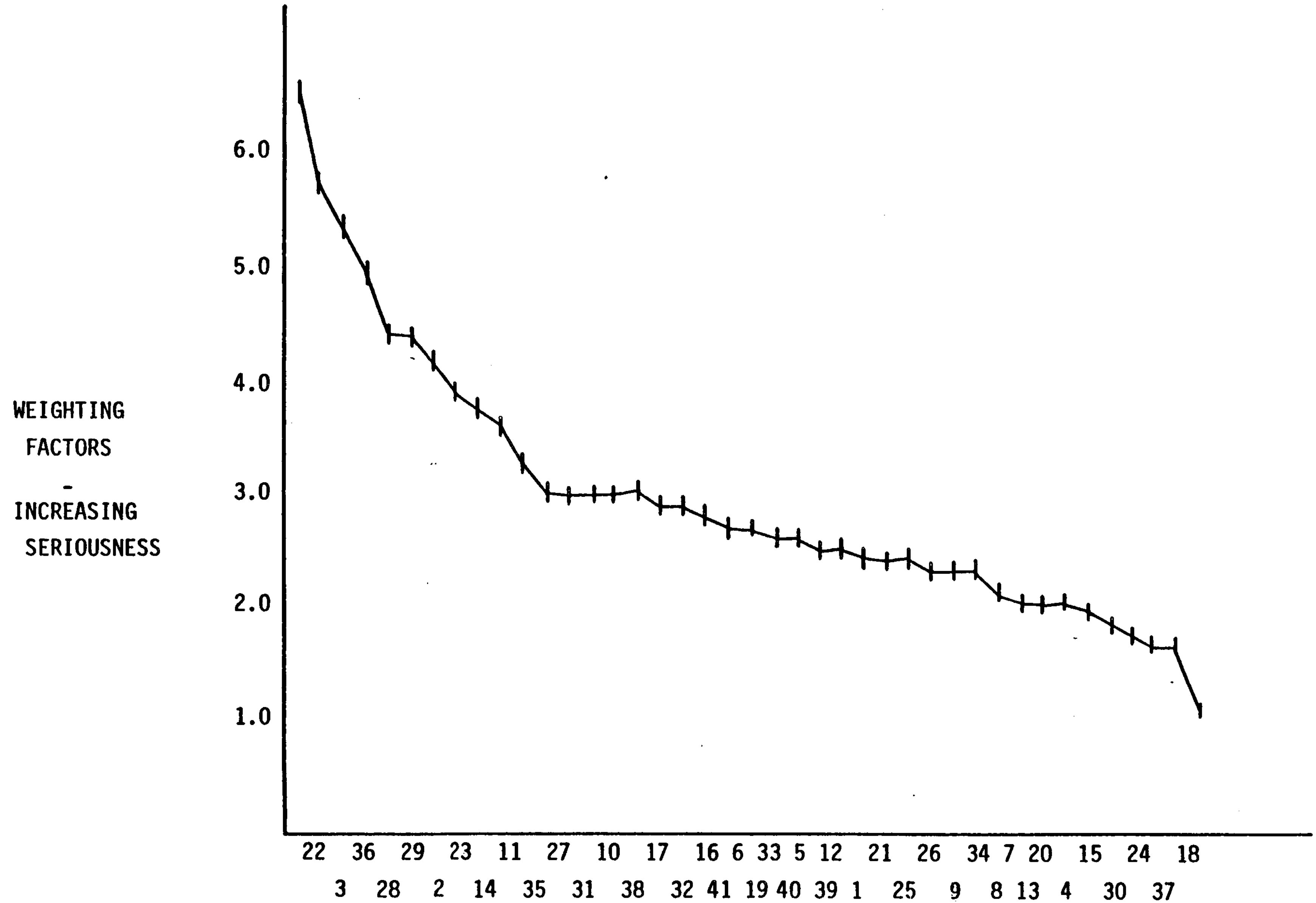

FIGURE 3. AGRICULTURAL AVIATION PROBLEM PRIORITIES

FIGURE 4. GENERIC "PACKAGING"

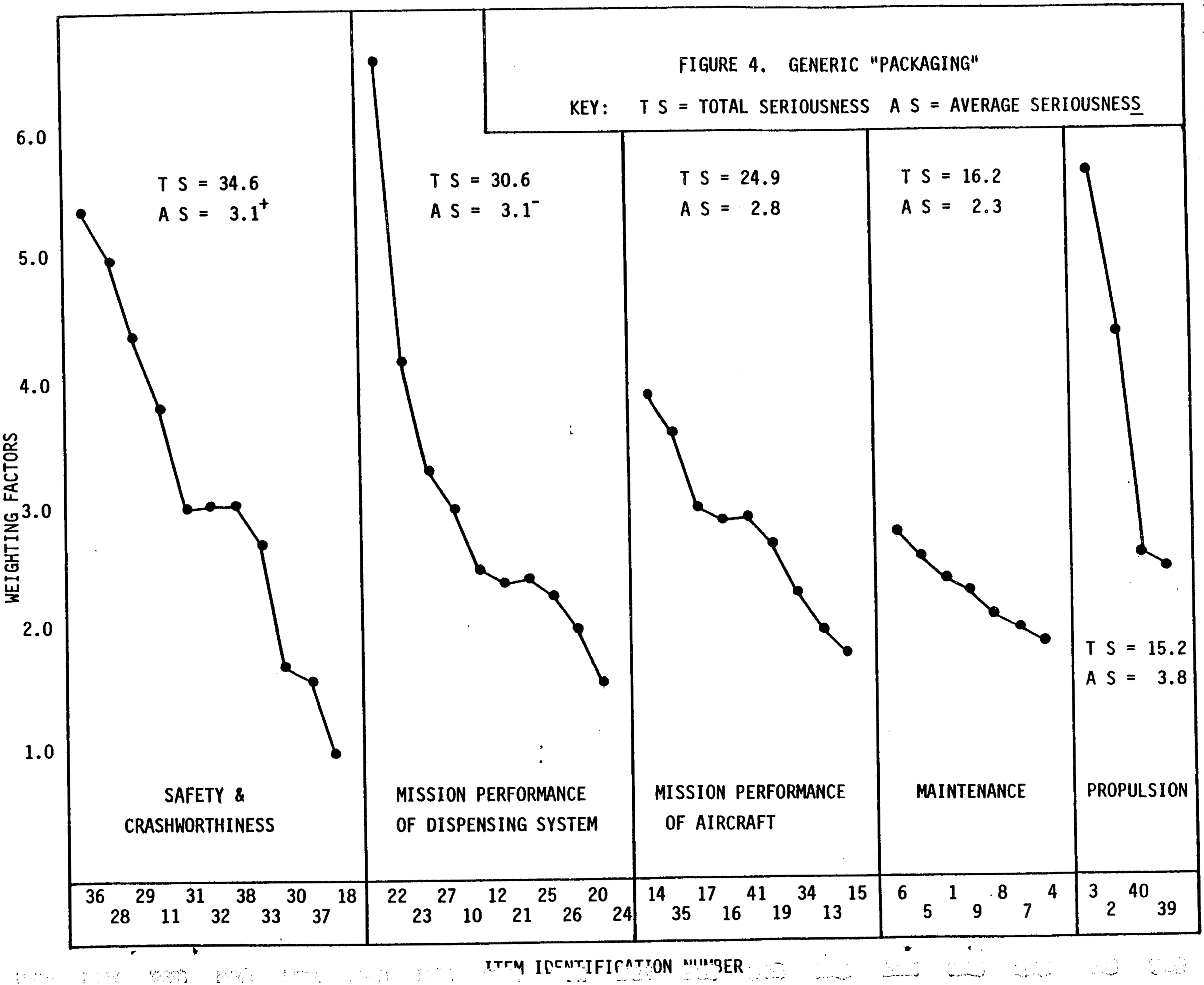

TABLE 5

GENERIC "PACKAGING" OF PROBLEM AREAS

Generic Group	Weight	No.	Item
I. Safety and Crashworthiness	5.4	36.	Protecting pilot from toxic substances
	5.0	28.	Capability of cockpit area to survive a crash
	4.4	29.	Fire prevention and protection
	3.8	11.	Protecting ground crew from toxic materials
	3.0	31.	The accumulation of dust and chemicals on windscreen
Av. Ser. = 3.1	3.0	32.	Cockpit visibility (unobstructed view)
	3.0	38.	Ground obstacle detection and avoidance
	2.7	33.	Location and design of cockpit flight and emergency controls
	1.7	30.	Maintaining A/C control during dump
	1.6	37.	Mid-air collisions
	1.0	18.	Stall warning
II. Mission Performance of Dispensing System	6.6	22.	Drift
	4.2	23.	Uniform dispersal pattern--providing even lateral (side to side) distribution in a swath
	3.3	27.	Determining uniformity of coverage and dosage of application during flight
	3.0	10.	Ground handling of payload--proportioning, mixing, transfer, weighing, speed of operation
Av. Ser. = 3.0	2.5	12.	Adjusting dispersal systems to meet new application requirements
	2.4	21.	Monitoring flow rate
	2.4	25.	Effects of varying ground speed on dispersal
	2.3	26.	Confirming uniformity and concentration of application post flight
	2.0	20.	Monitoring of individual nozzles/gates in flight
	1.6	24.	Selecting dispenser turn-on/off points
III. Mission Performance of A/C	3.9	14.	Short take-off and landing capability of the A/C
	3.6	35.	Cockpit comfort
	3.0	17.	Steep, short-radius turn capability of the A/C
	2.9	16.	Climb-out/dive-in capability of the A/C
Av. Ser. = 2.8	2.9	41.	Flexibility of A/C to meet different AG requirements
	2.7	19.	Swath guidance
	2.3	34.	Stick force effort during maneuvers
	2.0	13.	Rough-terrain TO and landing capability of the A/C
	1.8	15.	Cruise speed
IV. Maintenance	2.8	6.	Availability of replacement A/C engine
	2.6	5.	Corrosion inspection and control
Av. Ser. = 2.3	2.4	1.	"In-the-field" repair and service of A/C
	2.3	9.	"Change-over" detoxification
	2.1	8.	"Flush-out" of dispersal system
	2.0	7.	"In-the-field" repair and service of dispersal systems
	1.9	4.	"Wash-down" of A/C, inside and out
V. Propulsion	5.7	3.	Engine reliability
Av. Ser. = 3.8	4.4	2.	Length of engine and accessory time-between-overhaul(TBO)
	2.6	40.	External A/C noise
	2.5	39.	Fuel consumption

CONCLUSIONS

On the basis of a nationwide poll of 625 members of the agricultural aviation community, it is concluded that:

1. Drift is the single most serious problem encountered.

2. "Propulsion" problems are the most serious as a generic group.

3. The differences among problems associated with specific, crop servicing operations may be more individually significant than can be determined from a generalized poll.

4. Although helicopter operations were not the focus of this study, the results obtained from a limited number of helicopter respondents suggests a significantly different array of problem areas than those of fixed-wing operators.

APPENDIX C

INTERAGENCY AGREEMENT

This appendix contains a draft copy of the interagency agreement that will be executed by the National Aeronautics and Space Administration, the Department of Agriculture, the Environmental Protection Agency, and the Federal Aviation Administration.

INTERAGENCY AGREEMENT

BETWEEN THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DEPARTMENT OF AGRICULTURE

ENVIRONMENTAL PROTECTION AGENCY

FEDERAL AVIATION ADMINISTRATION

I. Purpose:

The objective of this interagency agreement is to establish policies and procedures that will provide for working relationships between the National Aeronautics and Space Administration (NASA), United States Department of Agriculture (USDA), Environmental Protection Agency (EPA) and the Federal Aviation Administration (FAA) in support of common objectives, interests and statutory requirements. Specifically this agreement is directed toward applying the unique scientific, technological, and managerial capabilities and facilities of each of the four parties, through joint and cooperative projects to develop, test, demonstrate, evaluate and encourage operational use of emerging technologies for improvements in the precision, effectiveness, safety and environmental impact of the aerial application of materials used in agricultural production and vector control. This agreement is established to provide the framework within which an interagency program can be planned and conducted under terms to be defined by various subagreements and Memoranda of Understanding (MOU)

This agreement between the four parties provides for:

1. development and incorporation of various projects or tasks,

2. mechanisms for resource support, fund transfer and accountability,

3. individual and joint responsibilities,

4. establishing requirements for periodic, milestone and final reports,

5. procedures for issuing publications and press releases,

6. requirements for program evaluation and,

7. procedures for modifying or terminating agreement/or any subagreement.

II. Scope of Work:

The scope of work will be covered by individual MOU as developed, coordinated and approved by authorized representatives of the parties to each specific MOU. These MOU will identify the specific objectives of efforts as R&D programs, regional support and applications engineering and laboratory and field center relationships. Each MOU will be supported by specific plans including schedules, milestones, resources requirements and allocations, program and task rationale, responsibilities of each Agency, and documentation which will include periodic progress and financial reports as agreed upon by each party.

III. Joint Responsibilities:

Through independent actions which are mutually agreed upon, or through cooperative efforts (of committees or task-groups) the four Agencies will undertake the following:

1. Appoint an individual as an agency representative and member of an interagency steering committee which will:

   a. Act as the central point of coordination between the parties to this agreement.

   b. Review and concur in all proposed MOU and subagreements.

   c. Meet quarterly or as needed to review status, progress and problems in carrying out efforts under this agreement.

d. Jointly prepare guidelines for field activities to include the scope of the individual programs and estimate of the resources which may be available.

e. Notify the other Agencies at any time of priorities or resource changes which will cause significant modifications of activities being planned or conducted.

2. Designate, as appropriate, the Headquarters Office which:

   a. Will have primary staff interest in coordinating, communicating and initiating staff actions related to this Interagency Agreement;

   b. Will have primary staff interest in coordinating, communicating and initiating staff actions related to each supporting MOU;

   c. Will insure that planning and programming actions regarding resources are initiated in a timely manner, especially as regarding coordinating commitment of resources;

   d. Will maintain records of all MOU entered into under this agreement. Such records will be summarized for staff review as required, with one due date based on the annual budget call.

3. Periodically review the total program and provide reports of same to the responsible offices.

4. Within the organizational structure of each Agency undertake the necessary action to insure interagency coordination of activities related to programs falling within the scope of this agreement.

5. Jointly agree upon the reporting requirements for each subagreement.

IV. <u>Agency Responsibility</u>:

General:

Recognizing that no single agency has sufficiently broad expertise and/or facilities to address all facets of the problems encountered in the use of aircraft in the application of materials used in agricultural production and vector control, this agreement provides a mechanism for focusing the unique capabilities of each organization, through cooperative and joint efforts, toward a common objective.

Fundamental to the success of this agreement is a clear understanding of the responsibilities which are to be jointly undertaken by all parties. In this regard,

NASA Will:

1. Provide overall coordination and direction of the projects under this agreement.

2. Plan, request, justify and provide resources and facilities for technology development in:

    a. Aerial applications system design studies.

    b. Aircraft configurations, performance and flight characteristics.

    c. Liquid and dry material dispersal equipment.

    d. Aircraft and systems integration.

    e. Measurement and calibration equipment and techniques.

3. Designate field units to:

    a. Assure that the scientific, technical, and management aspects of the activities under this agreement are executed.

    b. Assure that the plans, actions and achievements are evaluated to preclude unnecessary duplication and that information describing the work is widely disseminated, particularly in the aeronautical industry sector, to promote maximum technology transfer.

4. Compile and publish a quarterly status report on the total activity conducted under this agreement.

USDA Will:

1. Provide a comprehensive statement of the impact of application system characteristics on efficacy of agricultural pesticides.

2. Within the resources available plan, request, justify, and provide funds to defray the cost of contracts, consummables and equipment procured under plans and programs under this agreement that relate specifically to the areas of interest and responsibility of the Department.

3. Review the progress of the work planned and authorized in each MOU.

4. Be responsible for the dissemination of information regarding the operations and applications of systems and instruments developed under this agreement that are of interest to agriculture and its mission including the possible adaptation and modification of aerial application technology to other types of pesticide applicators.

5. Designate a field unit to:

    a. Assure that the scientific and technical aspects of the activities under this agreement are coordinated and compatible with other projects and programs of the USDA.

    b. Assure that the actions and achievements are evaluated to preclude unnecessary duplication and that information describing the work is widely disseminated to achieve maximum technology utilization particularly in the agricultural user industry.

EPA Will:

1. Provide a statement of requirements outlining environmental problem areas associated with the use of aircraft in the application of pesticides.

2. Plan, request, justify, and provide the funds to defray the cost of grants, contracts, consummables and equipment procured under plans and programs under this agreement that directly support the EPA mission.

3. Review the progress of the work planned and authorized in each MOU.

4. Be responsible for the operational application of systems and instruments developed under this agreement that are relevant to the Agency's mission or statutory requirements.

5. Designate a field unit to:

   a. Assure the scientific and technical aspects of the activities under this agreement are coordinated and compatible with other projects and programs of the EPA.

   b. Assure that the actions and achievements are evaluated to preclude unnecessary duplication and that information describing the work is widely disseminated, particularly between state and local governments, to achieve maximum awareness and to stimulate technology transfer and utilizations.

<u>FAA Will:</u>

1. Be the principal U.S. agent in coordination of activities under this agreement with the USSR under the Aviation portion of the US/USSR Agreement in Cooperation in Transportation.

2. Provide an analysis of airworthiness criteria as currently applied to aerial application aircraft and identify requirements and potential problems in certification of future systems.

3. Plan, request, justify and provide funds to defray the cost of projects under this agreement that directly support the FAA role in certification of airworthiness.

4. Designate a field unit to:

   a. Assure the scientific and technical aspects of the activities under this agreement are coordinated and compatible with other projects and programs of FAA.

b. Assure that the actions and achievements are evaluated to preclude unnecessary duplication and that information describing the work is widely disseminated, particularly to the aeronautical services section, to achieve maximum technology transfer.

V. Resources Management:

Resources requirements on the part of each Agency will be based on plans supporting each MOU, as approved by the Agencies. Such plans will be reviewed annually by the office responsible for a specific MOU and the resource allocation for implementation will be predicated on national benefits and available resources by those offices. Each MOU will address specific procedures for procurement and disposition of property acquired under this agreement.

VI. Modification of Agreement:

The agreement and supporting MOU can be modified at any time by mutual agreement of the responsible representatives of the Agencies. Such modification must be in writing as an amendment for record.

VII. Duration of Agreement:

This agreement is effective for 7 years. At any time the agreement may be renewed for additional periods by mutual agreement between the responsible representatives of the Agencies. The periods of commitment covered by individual MOU, except for planning continuity, shall not extend beyond the duration of this agreement or its renewals. This agreement may be terminated by mutual consent at any time, or unilaterally within 90 days written notice by the withdrawing Agency.

VIII. Public Information:

The mechanisms for release of information to the public will be addressed in each MOU. This will include appropriate channels of coordination and provisions for delivery of copies of all such communications to the corresponding Agency.

A. M. Lovelace
Deputy Administrator
National Aeronautics and
Space Administration

Date ____________________

M. Rupert Cutler
Assistant Secretary for
Conservation Research and
Education
United States Department
of Agriculture

Date ____________________

Barbara Blum
Deputy Administrator
Environmental Protection
Agency

Date ____________________

Langhorne M. Bond
Administrator
Federal Aviation Administration

Date ____________________